Alessandra Colocci

AN INTERCONNECTED PATH FOR SOCIAL-ECOLOGICAL SYSTEMS

Decoding human-nature interactions to foster a resilient and sustainable development

FrancoAngeli

Nuove Geografie. Strumenti di lavoro

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Collana diretta da Andrea Pase (Università di Padova)

La collana, nata nel 2014 da un'intuizione di Marina Bertoncin, propone esplorazioni sui nuovi modi di rappresentare, studiare e discutere il territorio. Mutano infatti le forme della spazialità e si affacciano nuovi attori: sorgono così tematiche inedite e altre – più consolidate – richiedono di essere interpretate con sensibilità diverse. Sulla base di proposte teoriche e metodologiche al passo con il dibattito internazionale, la collana dedica particolare attenzione al lavoro di terreno, all'indagine di campo, all'ascolto del territorio e delle soggettività che in esso si esprimono.

La collana si rivolge in primo luogo alla comunità dei geografi e ai colleghi di altre discipline che studiano il territorio, ma ha l'obiettivo di allargare la platea degli interessati ai nuovi "discorsi sul mondo".

I testi presentati sono esaminati in prima battuta dal Comitato scientifico e poi sottoposti a doppio referaggio cieco, al fine di certificare la qualità dell'opera e la sua congruenza agli obiettivi della collana. La *peer review* è sempre intesa come un momento di crescita e di ulteriore sviluppo del lavoro scientifico e non come una mera attività di valutazione.

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Cover Image: “A fluid interface: where social and ecological paths reconnect”,
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PART III – Qualitative assessment

Foreword

*Antonella Pietta**

We live in times of change. The impacts of human activities on the planetary conditions are exerting heavy tolls on both human and non-human communities. Indeed, natural ecosystems are transforming, destabilised in their equilibria and moving towards new ones. The consequences of this transition are easily found in the devastating events that are affecting cities and societies worldwide: heavy rains, overwhelming floods, along with grave droughts and suffocating heatwaves are only some of the hazards that are becoming more and more present in the everyday life of people around the world, in escalating conditions of risk that threaten their very existence.

From a disaster risk reduction perspective, it has already been established that it is time to shift towards managing risks, abandoning the approach that attempted to deal with the effects of disasters: in such tumultuous times, this call must translate in a further shift to manage how humans interact with natural ecosystems and the resources they provide. In brief, a profound change at the interface between humans and nature is necessary, starting with recognising that we inhabit Social-Ecological Systems, that are complex systems not simply built of human and natural components, but rather moulded by the interactions occurring between those components. Given this premise, the contribution of Geography in investigating such a multifaceted intersection can be substantial, as this discipline is particularly apt to combine information and data from different domains to foster the understanding of intricate issues. In this case, the Geographical lenses are especially suitable to investigate how human communities can strengthen their resilience, that is their capacity

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to deal with disaster risks, while increasing their sustainability, that is their capacity to live soundly within natural ecosystems.

The present volume embraces this perspective, exploring the panarchical hierarchy and inherent interactions that model Social-Ecological Systems and then proposing an integrated approach to assess the resilience and sustainability of human communities, in relation to their surrounding environment, with a particular focus on flood risk. The aim of this study is to provide a tool to inform and support the local governance of Social-Ecological Systems in devising a renewed, common development path.

Preface

When discussing the path that should be undertaken in order to project the survivability of humankind in the long term, it is not sufficient to either focus on the benefits or on the menaces posed by the phenomena occurring in the surrounding environment. Indeed, natural processes provide essential resources and functions for human liveability, though a failure in the interface with those forces might lead to dreadful consequences for human communities. Therefore, it is necessary to identify a path that both tackles the risk of disasters and supports a sound social-ecological co-development, at the same time and with the same priority. The awareness of the inextricable interplay between maintaining human communities and valuing ecosystem services is consistently growing (Collier et al., 2013). Nevertheless, those two domains are still often maintained separated if not in contrast, especially during the designing processes of urban settlements, thus precluding an integrated planning as well as the ignition of positive synergies (Cariolet et al., 2016). Even in the concept of "first nature" as recalled by Smith while reconsidering the pioneering Marxist theories (1984), nature is still conceived as a pristine entity, divided from humans, though the first signs of the need to close this gap were beginning to emerge. Nevertheless, the concept of "second nature", as inherently modified or, rather, produced by human agency (Loftus, 2017; Smith, 1984) is still yet to be fully embraced, although such a theory would significantly reshape the understanding of human-nature relations and social-ecological systems. A decisive year was marked by 2015, when the United Nations endorsed two fundamental frameworks. Few months apart, the "*Sendai Framework for Disaster Risk Reduction 2015-2030*" (UNDRR, 2015) and the "*Transforming Our World: The 2030 Agenda for Sustainable Development*" (UN, 2015) were delivered, stating the principles that should guide the international endeavours fostering human development. In particular, the Sendai Framework came as a renovation and advancement of the resolves of the Hyogo Framework of Action (UNDRR, 2005), leading international efforts towards reducing disaster risk through the understanding of disaster dynamics and the implementation of appropriate measures to cope with and respond to adverse events. The focus is on inhibiting the conditions that induce disasters, either addressing existing critical issues or preventing the creation of new ones, broadening the range of engaged stakeholders as well as the domains of concern. At the same time, the 2030 Agenda built on the previous international discussions and agreements to identify a series of development goals to be achieved, that compose a multifaceted path to promote human well-being in terms economic, social and technological capacities, along with the preservation of natural assets. It is remarkable that in both documents a consistent cross-reference evidently emerges, delineating a common intent for a sound coexistence between humankind and the natural environment, and a common acknowledgment that achieving one is inherently dependent on the other. This standpoint underpins a fundamental concept: humans and nature are not separated entities, but rather form an interconnected, complex system, that might be addressed as a social-ecological system (Berkes & Folke, 1998). This terminology was introduced with the intention to emphasise the idea of "*humans-in-nature*", evidencing that the interrelation is so deep rooted that the boundary between what is "human" and what is "natural" is essentially volatile, if not artificial and arbitrary (Folke, 2006; Folke et al., 2010). Indeed, social-ecological systems are not just social systems, nor just ecological systems, nor a simple juxtaposition of a social and of an ecological system. These complex systems envision a multitude of driving forces: apart from the powerful determinant exerted by human intent and foresight (L. Gunderson, 2010), controlling variables might have different scales and timing of action on the two sides (Walker et al., 2006), translating in significant nonlinearity of response as well as potential surprise effects where the inner dynamics are not thoroughly understood (Jianguo et al., 2007). Indeed, when coming to the management of complex systems, optimising the efforts to strengthen one side of such system easily triggers detrimental effects for the other side (Folke, 2006). In other words, when the evolution of a system is moulded by the unceasing interplay and constant feedback loops between human and natural components, the resulting social-ecological system must be necessarily considered as a whole, otherwise the probability to fail in accounting for fundamental behaviours becomes prominent.

In light of the above considerations, the *objective* of the present research is to contribute to the understanding of human-nature interactions and to support a sounder coexistence within social-ecological systems, in the perspective of a thorough renovation of human communities in relation to the natural environment. This aim assumes a fundamental tenet, that is embracing change in order to maintain a system (Folke et al., 2010). It has already been acknowledged that the persistence of a social-ecological system necessarily entails adapting and transforming in response to the surrounding drivers of change (Walker et al., 2004). These two approaches refer to different strategies that a system might adopt. Indeed, "*adaptation*" implies shaping the present system and accommodating it to external or internal pressures, whereas "*transformation*" implies a fundamental reframing of the system in order to better cope with those drivers (Walker et al., 2004). In other words, a system might either introduce some adjustments within the existing development trajectory or reorganise itself in order to move on a new development trajectory (Lovell & Taylor, 2013). Nevertheless, as it is not possible to identify a solution that might fit any potential scenario, the persistence of a social-ecological system appears bound to a flexible approach, that is fostering a transformative adaptation to external and internal drivers of change.

In brief, the present discussion investigates the theme of reducing disaster risk, exploring the possible ways of strengthening complex social-ecological systems and of inhibiting the possible paths of destruction. Indeed, such a comprehensive approach is suggested from the very definition of disaster risk reduction as strategies and plans "*aimed at preventing new and reducing existing disaster risk and managing residual risk, […] contribute to strengthening resilience and therefore to the achievement of sustainable development*" (UNDRR, n.d.-c). As a consequence, the present research adopts the disaster risk reduction approach to the widest extension, that is as a holistic standpoint to comprehend and foster the interaction of humans and nature within complex social-ecological systems.

Lastly, this research adopts a geographical approach to the theme of disasters and their reduction. Indeed, Geography is a discipline inherently prone to acquire, systematise and fruitfully integrate information from a manifold of sources, different for typology and domain (Calandra et al., 2014). It follows that Geography is also especially apt to manage the complexity of social-ecological systems and of disaster risk conditions (Calandra et al., 2014; Marincioni, 2015). Notably, geographical researchers have long discussed around the conceptualisation as well as operationalisation of risk and disasters, although this discourse has gained momentum in Italy only in the last decades (Calandra et al., 2014; Forino & Porru, 2013; Porru, 2012). This is particularly interesting, given the high potential of the Italian area to provide meaningful cases to comprehensively study disasters due to its historical, significant susceptibility to a variety of hazards (Forino & Porru, 2013). Despite this relatively recent interest, the contribution of Italian geographers is growing and positively confronting with the many facets of disaster studies. For instance, attention has been drawn upon qualitative narrative of disaster resilience (Forino, 2012) as well as novel methods to quantify community resilience (Toseroni et al., 2016), the interrelation among hydro-geological emergencies and urban expansion (Gatto et al., 2023), the perception of local hazards (Gioia et al., 2021) and post-disaster reconstruction activities (Bonati, 2022), as well as methodologies to measure perceived social resilience (Carone et al., 2019). Furthermore, it is relevant to note that Italian geographers are similarly concerned with the investigation around sustainability and its facets, in a theoretical perspective (Grasso & Tàbara, 2019) as well as by means of quantitative approaches (Bagliani & Pietta, 2013) with relevant case studies in Italy (Pietta & Tononi, 2021; Randelli & Martellozzo, 2019; Tononi et al., 2017), also opening to the connection with the theme of resilience (Bagliani & Pietta, 2014). Evidently, the above mentions point at a portion of the wider production of the Italian Geography on these issues. Nevertheless, they corroborate the growing relevance of the discussion around disaster resilience and environmental sustainability in the Italian context. This research aims at contributing to this ongoing dialogue, fostering the reasoning around the nexus between resilience and sustainability, and thence proposing a novel approach for an integrated assessment.

Introduction

The United Nations Office for Disaster Risk Reduction (UNDRR) defines a disaster as a "*serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts*" (UNDRR, n.d.-a). In this definition a multifaceted problem is presented, where not only both human and natural elements interact, but they also can constitute either a source of threat or an element of susceptibility. When disaster risk is considered as the potential occurrence of a jeopardising disruption (UNDRR, n.d.-b), it becomes fundamental to identify the basic factors of risk (and thus of a disaster). Commonly, risk is described as the combination of a hazard, and of the exposure and vulnerability of some entities (Varnes, 1984). That is, a hazard represents the process that might negatively impact a system, whereas that system is exposed if located in an area prone to that impact, it is vulnerable if it is prone to suffer damages (UNDRR, n.d.-d). In brief, a risk exists only at the interface between threatening forces and susceptible elements.

Despite the early development of models aiming at conceptualising risk and disasters, a comprehensive representation of the complexity of social-ecological systems was hardly proposed. In this perspective, a suitable approach might be provided by ecological models. By definition, ecological models are meant to portray complex systems, hence they provide a reliable base for considerations concerning the complex relation of humankind with the natural environment (Burton, 1993). In general terms, ecological models either adopt two major approaches: equilibrium or non-equilibrium approaches. Equilibrium models would tend to avoid disasters at all costs, whereas non-equilibrium models assumes disasters as an integral part of the evolution and development system (Elkin, 2014). Consequently, non-equilibrium models appear to hold a significant potential to contribute to the disaster discourse, thus it is deemed meaningful to explore one of the most appreciated ecological models, that is the *panarchy*.

The panarchy model

The panarchy model (L. H. Gunderson & Holling, 2002; Holling, 2001) adopts a systems approach, beneficial to expose the multidimensional structure and the nonlinear dynamics of a complex system, declined either as an ecological or a social or a coupled social-ecological one (Allen et al., 2014). The hierarchy that emerges through this application of the systems approach is far from rigid: control is not exclusively exerted by larger components and transformations are not inhibited. Rather, the interactions among sub-systems allow for a continuous, mutual influence, hence changes happen at all levels and at any time (Allen et al., 2014). In brief, a panarchy is a complex system constantly evolving due to the exchanges of information and resources within and outside the system. Indeed, the name of the model itself hints at this. Although the term "panarchy" holds a distinctive history, dating back to the mid-19th century (OED, n.d.), Holling and Gunderson renewed the significance of this term. Where the first part reminds the Greek god Pan and its creative yet destructive power, the second part introduces a hierarchy that sustains the system in order to allow for experiments and restructuring (L. H. Gunderson & Holling, 2002). Following, a panarchy is characterised by two main features: the *adaptive cycles*, that describe the components of the system (i.e. a social-ecological system includes social components and ecological components), and the *interactions*, a series of feedbacks taking place among such components. Notably, within this framework a complex system might be reduced to a handful of key components (*adaptive cycles*), reasonably three to five, while still maintaining its basic features (Resilience Alliance, 2010). Similarly, the *interactions* can be reduced to a restricted range and still maintain the ability to fully represent the potential exchanges. Even though its powerful visualisation capacity might limit its application to descriptive studies, the panarchy is actually a versatile heuristics, able to support theoretical conceptualisations as well as the formulation of operative hypothesis to be empirically verified (Allen et al., 2014). In other words, along with the qualitative power of visual representation, also quantitative approaches might benefit from the application of this model (Angeler et al., 2016). Such flexibility seemingly justifies a further interest in exploring the mentioned characterising features.

Adaptive cycle

One of the fundamental assumptions of the panarchy model concerns the possible equilibrium of the system: fixed singularities of stability are rejected, in favour of multi-stable states that accept domains of stability and non-linear responses (Folke, 2006). The intrinsic transformability of a complex system is depicted not only as a characteristic of the overall system, but also of each of its components. In particular, a nested set of *adaptive cycles* forms a panarchy, providing the overarching hierarchy. At the same time, each *adaptive cycle* envisions a series of possible *phases* that trace a path of constant renovation. In this way, different *adaptive cycles* address components of different dimensions, but also different rates of change, where larger components hold a higher inertia towards change, whereas smaller components are more prompt to experiment new states (Holling, 2001). Notably, where each *adaptive cycle* represents a specific spatial scale, the inner *phases* account for the temporal scale of change.

Regardless of their scale, the *adaptive cycles* are similar in the dynamic of change. In this case transformability is interpreted through four main *phases*: reorganisation – exploitation – conservation – release (Fig. 1).

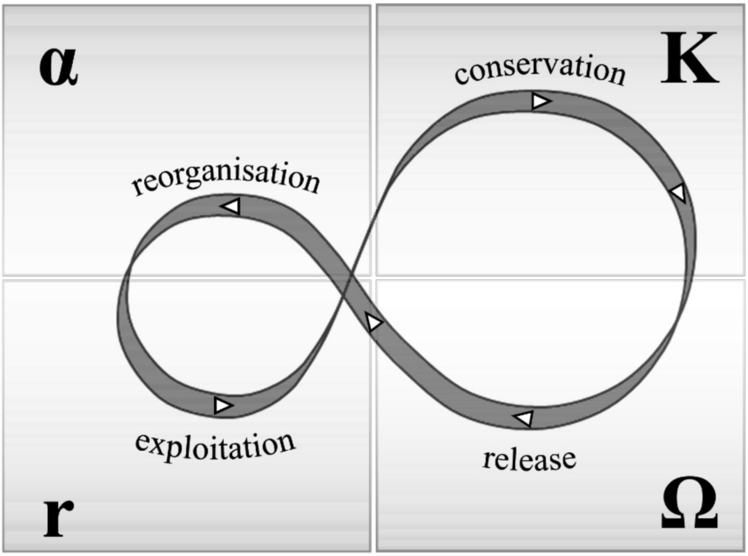


Fig. 1 - The adaptive cycle and its four main phases: reorganisation, exploitation, conservation, release (adapted from Holling, 2001)

These *phases* depict the growth, crisis and recovery of the potential of a component of the system. The same shape of the *adaptive cycle*, resembling the mathematical symbol for infinite, suggests the idea that the cycle is never-ending. A *phase* always follows an other, with slower processes building up the conditions for abrupt turns to eventually take place: the system component might come back to a structure similar to the previous one or, on the contrary, take advantage of a condition of "*creative destruction*" (Holling, 2001) to experiment a new architecture. In any case, the component will eventually undertake a path of development, moving away from the previous collapse. The meaning of the *phases* is synthetised by the related symbols (Fig. 1.1). The reorganisation and the release *phase* take inspiration from the Greek alphabet: they are α and Ω, the beginning and the ending. The development path commences when the *sub-unit* reorganises (α) the structure and copes with the crisis of the fundamental functions induced by the previous collapse. A collapse that eventually will happen again, when the path approaches once more the point that triggers the release (Ω) of the accumulated weight in terms of rigidities and constrains. The two other *phases*, r and K, describe what happens to the development path in-between. Here, the symbols recall the possible development behaviour of populations (Reznick et al., 2002), that might belong to one of two opposing and complementing typologies. The r-strategists focus on abundance: offspring are numerous, resources are widely consumed, growth is rapid. In contrast, K-strategists focus on efficiency: offspring is limited and attentively cared, resources are preserved, growth is slow (Reznick et al., 2002). In terms of change through the *adaptive cycle*, the system component that undertakes a new beginning (α) at first exploits (r) the available resources to explore and test new development paths, interlacing interconnections and accumulating capacities. Eventually, the condition grows in stability and the interest shifts towards a sounder conservation (K) of the achieved status, accumulating also rigidities. Here the cycle would eventually find its collapse (Ω). The impulse from r to K is also called *fore-loop*, while the transition from Ω to α *back-loop*. Notably, the dynamics of an *adaptive cycle* are inherently complex, as they are not only subject to inner variability and unpredictability, but they are also exposed to the oscillations of the overall system.

Interactions

As mentioned, the development of a complex system is driven by the relations between the *adaptive cycles* (that is, among the components of such system). Such relations might assume different shapes, but in general two main typologies have been recognised: the *remember interaction* and the *revolt interaction* (Fig. 2).

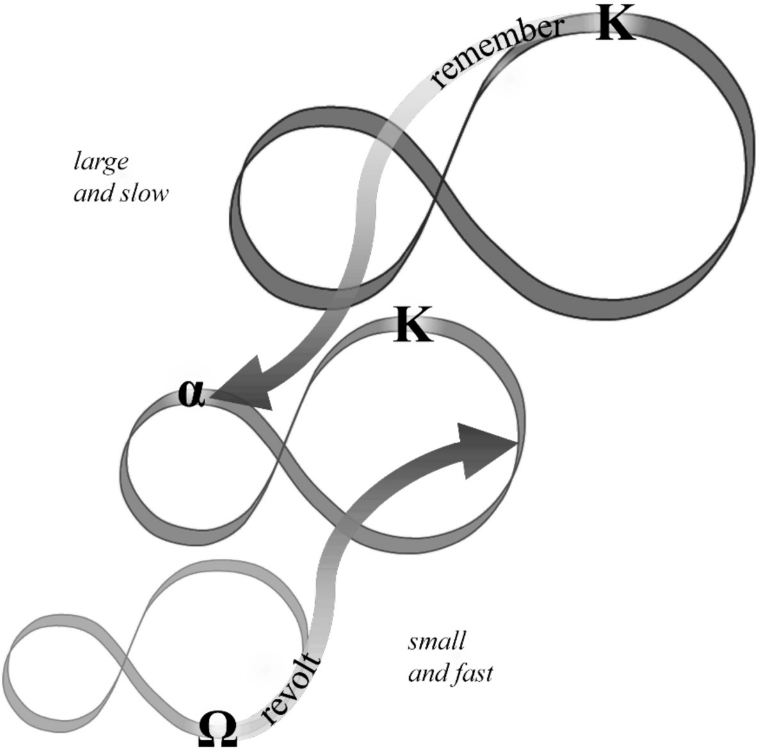


Fig. 2 - The nested adaptive cycles that form a panarchy and the two main interactions that may occur: remember and revolt (adapted from Holling, 2001)

In fact, either the *interaction* contributes to enrichen and stabilise the system or the *interaction* triggers the spread of unstable and destabilising conditions (Angeler et al., 2016). The difference relies not only on the effects, but also on the direction of the *interactions*: they are either cascading or escalating between the *adaptive cycles* of the panarchy (Holling, 2001). In particular, the *remember interaction* is a cascading, stabilising force. It describes a situation where a larger and stable component (conservation *phase* (K) of the *adaptive cycle*) provides its accumulated knowledge and experiences to support a smaller, collapsed component to exit the *back-loop* and move towards the reorganisation of a new development path (α-*phase*). The name "remember" hints at this, as if the system would share the accumulated wisdom to foster stability (Holling, 2001). On the contrary, the *revolt interaction* is an escalating, disrupting force. It occurs when a smaller component is in a status of destabilisation (Ω-*phase*) and ignites the collapse of a larger component that is building up rigidities (K-*phase*). In this sense it is a "revolt", because smaller and rapid levels overwhelm larger and slower levels of a system, shaking the overall equilibrium (Holling, 2001). It emerges a peculiar facet of the *interactions*: they appear only when there is a proper "alignment of the stars" (Holling, 2001). That is, only when the system components occupy the respective susceptible positions of the *adaptive cycles*, all at the same time, these *interactions* might set off and thence influence the development of the system (Allen et al., 2014). This is especially relevant with regards to the disruptive potential of the *revolt interaction*: only when the vulnerabilities align within a system, it is possible for the destabilising forces to propagate throughout the levels. This results in a threating power of escalating disastrous events (Pescaroli & Alexander, 2016), but it also means that radical transformations are reasonably rare (Holling, 2001). Nevertheless, this conclusion is still aligned with the primary assumption of the panarchy model, that embraces change and adjusted equilibria. In Holling's words, "the whole panarchy is therefore both creative and conserving. The interactions between cycles in a panarchy combine learning with continuity" (2001, p. 399).

Critical issues

Since the panarchy heuristic plays a central role for the present research, it might be significant to explore some possible issues.

To begin with, even though it is a "(adaptive) cycle", it has been observed that the *phases* might not be universally valid and in particular they might not necessarily come into a strict succession (Gotts, 2007). Although there are evidences for intrinsic cyclicity, there should also be cautiousness in attributing an absolute predictive capacity to the *adaptive cycle* (Abel et al., 2006). In particular, an *adaptive cycle* might experience a peculiar status where change is strongly constrained: this might happen because it has fallen in a *poverty trap* or in a *rigidity trap*, that are identified as conditions of maladaptation (Holling, 2001). An *adaptive cycle* might fall into a *poverty trap* when its resources and diversity are either internally dilapidated or externally extinguished. This condition of low availability of assets, capacities and interconnections inhibits positive renovation and forces the cycle to linger in the *back-loop*, threatening a similar fall to the other components of the panarchy (Holling, 2001). Conversely, a *rigidity trap* might occur when a component has maximised the use of available resources, its processes are tightly controlled, and it might have developed a high resistance against drivers of change. Here is the problem, as this kind of maladaptive system might be unable to embrace positive change and to escape from this perverse optimisation (Holling, 2001). Similarly to the *poverty trap*, such undesirable state might stiffen the overall panarchy and thence inhibit the overall variability (L. Gunderson et al., 2017).

In addition, the *remember* and *revolt* are commonly considered the major types of *interaction*. Even though their dynamics have been recognised in several systems (Holling, 2001), it has also been suggested that other forms might occur. In particular, it might happen that the same effects are manifested although the *interactions* follow in a reversed direction (Redman & Kinzig, 2003). This is especially threatening for the *revolt interaction*. Indeed, it suggests that instabilities have the potential to move both upwards and downwards the panarchy levels, that is both escalating and cascading forces should be expected (L. Gunderson et al., 2017).

Panarchies of complex systems

The panarchy effectively supports a deeper comprehension of the human, natural and coupled human-natural systems. Indeed, this heuristic has been fruitfully employed in several endeavours aiming at the explanation of observed dynamics, either focusing on the *adaptive cycle* itself or rather developing a broader panarchy (Garmestani et al., 2009). For instance, some traces of such operative applications can be found in the first explanatory works of the panarchy model: forests, coral reefs as well as societal changes and renewals are discussed by Holling (2001) to ground the description of the *adaptive cycles* and of the dynamics of the hierarchies.

Nevertheless, many other examples might be retrieved from the broader literature. In particular, it has been suggested that environmental issues might be modelled through panarchies, in order to comprehend the complex structure of natural ecosystems, that is interconnected and develops across multiple scales of space and time (Angeler et al., 2016). In this way, environmental management might rely on an integrated model to guide the enhancement of comprehensive strategies. Indeed, the panarchy recognises interdependencies, feedback loops and nonlinearities, as well as their double-fold potential to destabilise or maintain the architecture of the system. Nonetheless, some knowledge and data constraints prevent from an extensive application of the panarchy model in this domain. Hence, it was suggested that field experiments should further the understanding of the complex dynamics of natural systems, especially by identifying the critical variables and processes pivotal for their long-term persistence. In this regard, quantitative methodologies are especially recommended (Angeler et al., 2016).

A quantification effort was applied to marine systems. In particular, the ability of the *adaptive cycle* to model of the phytoplankton communities of the Baltic Sea was tested (Angeler et al., 2015). In this case, quantitative data concerning water and phytoplankton characteristics would fit the four main *phases* of the *cycle*. It was observed that the *adaptive cycle* properly describes the recognised ecological patterns, and it efficiently complements the theories, enriching the representation of the ecological dynamics though a comprehensive perspective on the blooms and development of phytoplankton communities throughout the seasons. Consequently, it is suggested that the *adaptive cycle* might hold the potential to shift from a mere interpretative paradigm to an heuristic suitable for empirical validation and, furthermore, for informing environmental policies and management (Angeler et al., 2015).

Other attempts sought to recognise panarchies in the social domain. A peculiar study concerned the development of port areas, with the aim of devising a management tool to foster a sounder resilience (Vonck & Notteboom, 2016). Thus, rather than as an explanatory tool, the panarchy theory was adopted to investigate the critical aspects of the complex dynamics occurring when several stakeholders interact. Here, the panarchy framework revealed examples of multi-stable states within a port development or the occurrence of the confinement in a *rigidity trap* when some highly focused development strategies are enacted. In other words, the panarchy framework appeared suitable to assist in the interpretation of some processes and at the same time in informing future management strategies (Vonck & Notteboom, 2016).

Some other research efforts concerned societal dynamics in the context of climate change adaptation (Park et al., 2012). The objective aimed at developing a comprehensive framework to support local authorities when taking action against environmental changes. Hence, different conceptual models dealing with transition, transformation and adaptation processes were examined and integrated, including the *adaptive cycles* and the related interacting hierarchies. In particular, the panarchy model resulted highly complementary to the other discourses, supporting the description of adaptive management as a series of decisions and actions that inevitably crosses scales and time, influencing the development path of the overall complex system (Park et al., 2012).

Since the panarchy framework inherently acknowledges the interrelations within a complex system, one of the most relevant applications relates to settings where natural components are decisive to human activities, such as in agricultural systems. A study concerning Dutch dairy farm system employed ecological indicators (such as nitrogen and soil organic matter) as a proxies of the ongoing transformations and processes (van Apeldoorn et al., 2011). Among the other conceptual frameworks, *adaptive cycles* and panarchy contributed to the modelling effort. In particular, it was found that dairy farming management tends to simplify the *adaptive cycle*, altering the commonly observed sequence of *phases* in natural settings. Human interventions allow to optimise the productive rate by artificially supplying nitrogen when natural processes would tend towards a stabilisation and then the minimum content of nitrogen. That is, human components are able to influence the natural components of the complex system, to the point of compromising their "naturalness". The analysis also suggested that the concept of resilience might be a matter of scales: this kind of dairy farms are highly adaptable to external pressures because of their massive intervention on natural processes, but this same characteristic is the cause of an un-sustainable and un-resilient system on a higher scale. On the other hand, the discussion focusing on soil organic matter concerned a multi-scale and multi-temporal social-ecological system. In particular, the panarchy framework allowed to investigate how traditional management might be more influenced by societal expectations of rapidly achieved results rather than natural constraints, while innovative management strategies tend to reconnect with the slower ecological pace of transformation. In this perspective, agroecosystem governance approaches are expression of two opposite timeframes: short-term when dominated by socio-political pressures, long-term when aligned to natural processes (van Apeldoorn et al., 2011).

A further case study concerned the deep interconnections between humans and nature occurring in an agro-pastoral system settled in a riverine area. There, the social-ecological system would encompass different components (social, economic, biophysical), as well as different scales (local, regional, national) (Walker et al., 2009). The *adaptive cycle* metaphor was effectively applied in order to trace the transformations that such complex system had undergone through time and to identify a pattern of change in the resilience of all its components. Indeed, it evidenced the relations among agricultural techniques, consequent alterations of natural processes (of both ecological and water ecosystems), and thus the reorganisation of productive activities. Notably, resilience was discussed both at a single-component level and at a general level. This appears significant when it had already been highlighted that systems highly resilient to a specific threat might be sensibly more susceptible to others. Overall, this study based on the *adaptive cycle* supported the identification of suggestions for future management strategies intended to foster a compromise between social demands, economic viability and biophysical equilibria (Walker et al., 2009).

It appears particularly significant to explore the cases where changes at a certain scale of the social-ecological system significantly impact an other scale, due to the mutual, tight interrelations. A study about the quinoa farming activities in the Bolivian mountains provides a possible answer, interlacing the local social habits, the evolving economic demands and the natural processes that support the quinoa production (Winkel et al., 2016). A panarchy model simplified the inner complex feedbacks, revealing how economic pressures and political resolutions impacted the social domain, with escalating consequences on the biophysical processes, to the point of moving them towards critical thresholds. It suggested how, especially in agroecosystems, anthropogenic drivers play a pivotal role in determining the development path of the overall social-ecological system. In this case, the panarchy model helped to gain insights to design future management strategies, in order the promote a renewed equilibrium between human processes and natural landscapes. Observed critical alignments within the different *adaptive cycles* might become critical early-warnings for the future, and even though a measure fitting for all situations might not exist, it is advised to support adaptive and integrated governance efforts in order to prevent the social-ecological systems from crossing compromising no-return thresholds (Winkel et al., 2016).

A further example was recognised in the Italian Alpine grasslands, where a traditional pastoral system was examined (Soane et al., 2012). This farming activity is centred on a household that live in close contact with the unique, local natural landscapes, although profound changes in this structure occurred the recent decades. The panarchy was employed to assist in identifying the major drivers of change, attempt to associate a quantitative dimension to the alternation of *adaptive phases* and thus guide the investigation on the overall vulnerability of the social-ecological system. Natural, social, political and economic drivers were comprised, covering an extensive range of spatial and temporal scales. The examination of different farming regimes allowed also to draw attention on the different shapes that an *adaptive cycle* might assume, depending whether the focus would be primarily on nature conservation or agricultural management. Even though panarchy was essentially adopted as a qualitative metaphor to sustain the comprehension of complex interdependencies, the model allowed to identify some significant quantitative parameters. These variables could be further refined through integrated approaches, that is engaging local stakeholders and social actors, to develop informative thresholds on the alternation of *adaptive cycle* shifts (Soane et al., 2012).

When studying coupled social-ecological systems, the investigation around resilience might further be enriched by introducing sustainability in the discourse, although only recently this multi-disciplinary approach has gained attention. An example is the case study that considered complex social-ecological systems, settling on a community level and questioning the escalating and cascading consequences of policies, community cohesion, economic drivers and their meaning for the sustainability of the overall system (Berkes & Ross, 2016). In particular, the model supports a multi-level visualisation of the occurring *interactions*, that results especially significant in highlighting the limitations of single-discipline or single-level discussions concerning sustainability. Indeed, it suggests that in some cases detrimental drivers of change (e.g. economic demands) might be underestimated if the analysis is too narrow, but also that some drivers might act at a level too far from the influence of smaller components. This further hints at the need to prompt different development paths for different scales, for example enhancing solutions viable for local-level application. Eventually, this complex hierarchy reminds that policies, directed towards both resilience and sustainability objectives, should not be considered as external pressures to the system, but rather as operating at a specific level of that system. That is, their design and consequences are an integral part of the complex social-ecological system, hence their development should be influenced by the characteristics of the social-ecological system and the impact of their enactment should be monitored (Berkes & Ross, 2016).

The close social-ecological interdependence is especially evident in the case of Small Islands Developing States (SIDS), where it is particularly relevant to discuss both environmental sustainability and disaster resilience. The panarchy framework was applied to the Bahamas (Holdschlag & Ratter, 2013, 2016) to shed some light on the environmental management of the island. It was possible to evidence how the current policies and economic drivers are inducing profound changes to the local environment, potentially leading to critical thresholds. On the other hand, citizens, especially younger generations, appear aware of such alterations and are promoting the adoption of different practices, at all levels. That is, internal drivers of change that have degraded the surrounding environment might become advocates of a sounder coexistence with nature, reversing the looming crucial impacts. It was also possible to evidence that without the active engagement of local communities in sustainability efforts as well as in building local resilience, top-down management strategies are likely to fail, especially when dealing with severe hazards (Holdschlag & Ratter, 2013).

An other case study, set in the Island State of Grenada, focused on local governance (Holdschlag & Ratter, 2016). In this case, an overwhelming driver of change was a hurricane that destroyed social, economic and natural assets, thus exposing the lack of preparation of the local community to face such extreme events that led to the collapse of the social-ecological system. In spite of notable internal efforts, this condition could be effectively reversed only thanks to external (hierarchically higher-level) assistance. Nonetheless, the local community did not just passively accept external aid, but rather it seized the chance to learn from the disaster and innovate its structure, adapting local assets to the surrounding conditions. Actually, this renovation allowed more efficiently to absorb the impact of a following hurricane, thus limiting the potential consequences. The panarchy model not only allowed to better comprehend the development path of the community, but it evidenced how cross-scale *interactions* might disrupt as well as stabilise a system. This is particularly significant as the components of a social-ecological system are constantly influenced by each other, when mutual learning and adjustment to the respective equilibria should inspire innovative, transformative and multi-dimensional local management strategies (Holdschlag & Ratter, 2013, 2016).

When studying disasters, two *phases* especially draw attention: the moment of collapse and that of restoring previous functions (that are, in the *adaptive cycle* metaphor, the *release* and the *reorganisation phases*, respectively). The historical development of the Rodrigues islands (Mauritius) was examined under these assumptions (Bunce et al., 2009). The panarchy framework exposed the devastating effects of natural hazards on human assets, the potentially missed chances of renewal and how limited resources prompted the adaptation of economic activities. Also, it effectively explained a particular cascade of events triggered by a cyclone and evolved in a spiral of further collapses. As attempts of restoring the fundamental activities did not seem sufficient, the analysis identified some variables operating at multiple levels that possibly explained such persisting crisis, such as mismanagement of natural resources, societal marginalisation or economic demands. In brief, this investigation supported the hypothesis that, after a disaster, complex systems might get stuck in a state that prevents renovation. Here, connectedness and cross-level *interactions* might turn either detrimental, if further obstructing the development path, or pivotal, if supporting a renewal. It derived that when designing and implementing management policies, it is fundamental to carefully evaluate the most beneficial level of application, to take into account multi-dimensional feedbacks (Bunce et al., 2009).

When focusing on human systems, critical infrastructures play a pivotal role in case of a disaster (Pescaroli & Alexander, 2016). These infrastructures are the physical and technical assets fundamental to perform social, economic or operational functions, both in routine and in emergency conditions (UNISDR, 2009). It follows that the disruption of a critical infrastructure might endanger the overall system, while their efficiency has the potential to sustain a prompt response to adverse events. This potential resides in the distinctive feature of critical infrastructures, that is their inherent and extensive interconnection with the wider system. Here, the panarchy heuristics suggested that the cascade of collapses from critical infrastructures to other components of a system might occur only under the condition of an alignment of vulnerabilities. Therefore, it should be encouraged a shift from the traditional analysis based on possible failures to an innovative approach that focuses on the points of vulnerability in a complex chain of assets. In other words, when the range of possible sources of threat are too wide to be thoroughly anticipated, it might still be possible to identify the susceptible components and thus act on them, in order to inhibit the spread of undesired conditions (Pescaroli & Alexander, 2016).

This brief exploration of the panarchy literature suggests that this heuristic has been appreciated for its potential to interpret the multi-dimensional structure of a social-ecological system, addressing the detrimental consequences as well as the reinforcing potential of cross-scale *interactions* among different components of the system. Resilience and sustainability issues seem to benefit from the application of the panarchy perspective, especially when disruptive events bring to the surface the inherent interdependencies. At the same time, even though considered together, it seems that a real integration of resilience and sustainability discourse within the context of the panarchy heuristics is still incomplete. Furthermore, although there have already been hints of possible differences in the structure of the *adaptive cycle*, it might be interesting to further explore such *interactions* and the potential implications of their reversed direction. The following paragraphs aim at developing such themes: the objective is to move from the discussed research efforts towards a further comprehensive, theoretical paradigm.

PART I – Theoretical framework

1. A Social-Ecological Panarchy

Before furthering the discussion concerning resilience and sustainability in the panarchy framework, it might be beneficial to focus on a specific social-ecological system, in order to maximise manageability, while retaining an appropriate level of generalisation.

In the present case, it might be interesting to start from the roots of the panarchy theory, that is the systems approach. In this regard, Jackson and colleagues (2010) suggested a series of steps, revised as:

1. identification of the components of a system and composition of the related hierarchy;
2. identification of the boundary of a system;
3. identification of the functions and of the interactions of each component;
4. definition of the system's environment;
5. synthesis of the system;
6. proving the system and identification of emergent characteristics.

Notably, the last step is more operational in nature and thence might be more suitable for the discussion to come.

The first step requires identifying the components of the system of interest, then grouping them in overarching classes and form a hierarchy. In this case, the focus is social-ecological systems, and previous research efforts remind that any complex system might be reduced to three to five main components of a panarchy (Resilience Alliance, 2010). In this case, it might be possible to recognise three main components: an anthropic component, including any process and asset that pertain to human activities, a first natural component, that describes the physical processes of the environment, and a second natural component, that comprises the broader ecosystem services. Although it is true that ecosystem services are performed by means of physical processes, the intention here is to differentiate between the dynamics that occur at a local, rather small scale (that can be reduced to physical dynamics) and the wider processes that involve higher spatial and temporal scales. In particular, the natural processes component focuses on a local scale, addressing phenomena that evolve in a rather rapidly; on the contrary the natural ecosystems component concerns a higher scale, with a rather slow speed of change. Within this architecture, the anthropic component might be considered between the other two components, since human activities have the potential to extend over local biophysical spaces, while they are surrounded by the wider natural ecosystems. Notably, these considerations partly respond to the third step of the procedure.

Still, it is necessary to define the boundaries of the complex system, and the operating environment. In particular, it is time to characterise the specific system, identify the functions performed and expose of the possible mutual influences among the components. In this phase, it might be appropriate to bring in the contribute of disaster studies. Even though some more details will be added later, it is already significant to consider the relevance of flood risk for human and natural communities, that is every day more evident and its disruptive potential is even increasing, also due to the ongoing environmental changes (IPCC, 2022). Consequently, here a flood risk scenario is assumed as the overarching setting. It follows that the system of interest should capture flood dynamics, including biophysical as well as anthropic processes. Considering the layout of the present social-ecological system, the natural processes component would describe the local hydrological processes that might impact the anthropic component developed around the hazardous area. Although floods might come from rivers as well as other water-related processes and events, here it might be beneficial to consider a riverine area, so that the overarching natural ecosystems component might be clearly identified as a river basin. In this case, the watershed comes to demarcate the boundaries of the system. Notably, in terms of operating environment, it also suggests that what lies within a river basin would be comprised within the system, while what remains outside the watershed might still interact and influence the development of the system, but as an external driving force.

At this point, it is possible to come to a synthesis of the system, in particular to visualise as a Social-Ecological Panarchy (Fig. 1.1):

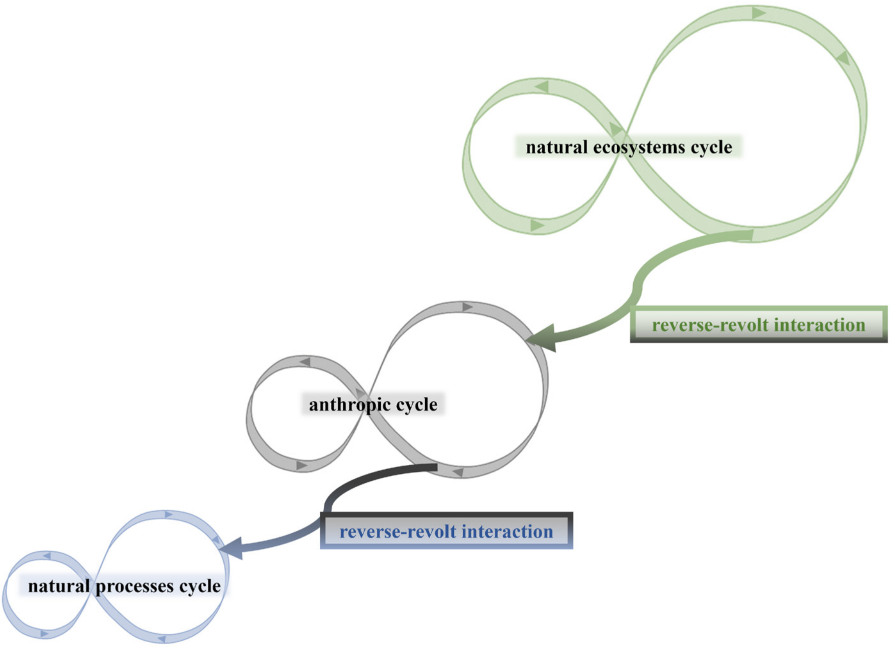
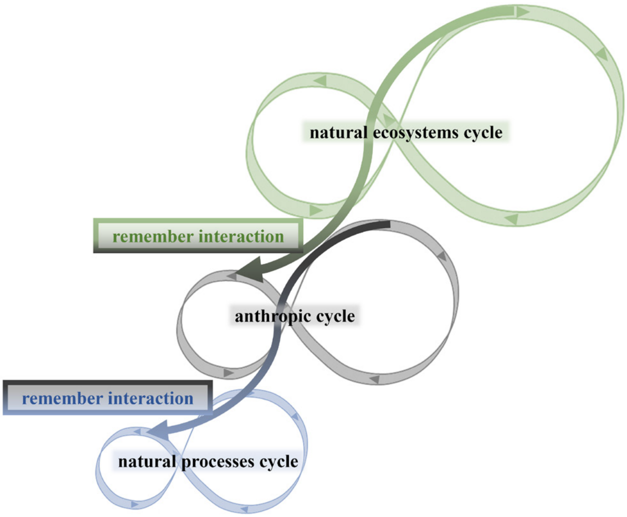


Fig. 1.1 - A social-ecological system represented through the panarchy model. In this example, the social-ecological system is a river basin, hence the three adaptive cycles represent the functions of the ecosystems (natural ecosystems cycles), the human assets and processes (anthropic cycle) and the physical processes of the riverine area (natural processes cycle)

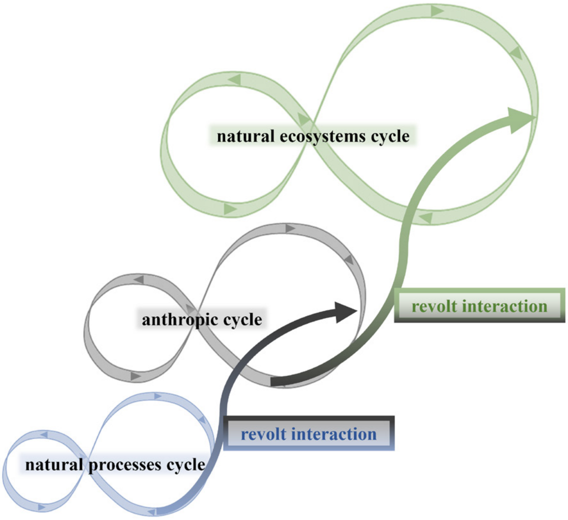
1.1. Phases and interactions within a Social-Ecological Panarchy

The features emerged in the literature thoroughly apply to the introduced Social-Ecological Panarchy, though in this case it might be especially relevant to further investigate the *interactions* between the *adaptive cycles*.

To begin with, it might be interesting to examine the *interactions* as originally developed by Gunderson and Holling (2002) as incorporated within the Social-Ecological Panarchy (Fig. 1.2).



(a)

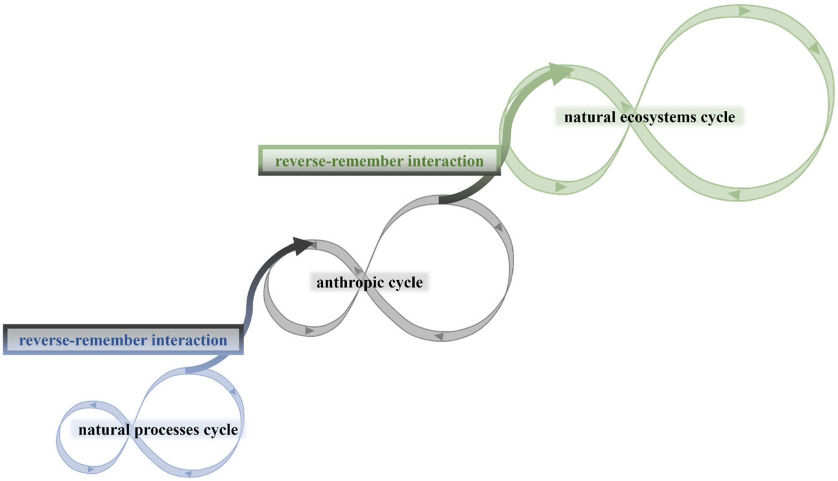


(b)

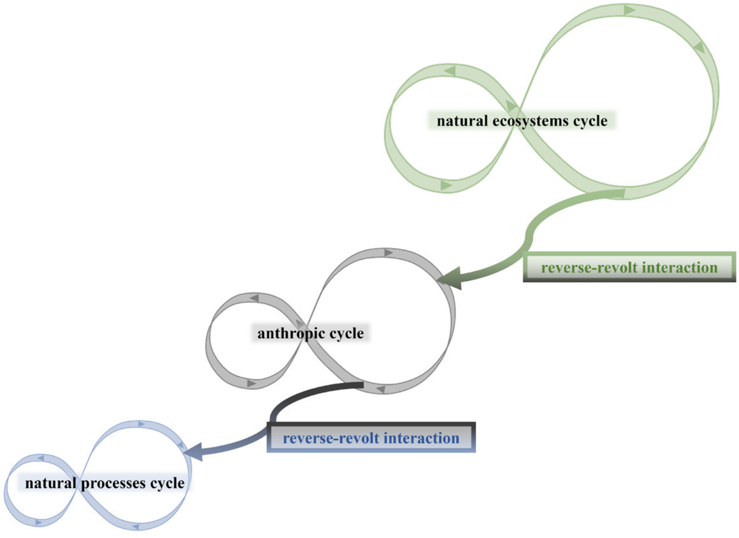
Fig. 1.2 - A Social-Ecological Panarchy with the three constituting adaptive cycles and the two main interactions, remember (a) and revolt (b), in the two possible configurations

Some examples might facilitate the interpretation of their meaning in this context. As mentioned, the *remember interaction* describes a condition where a stable system component intervenes to support the recovery of a smaller component lingering in the *back-loop* because of a collapse (Fig. 1.2a). This might happen when a human community has suffered high damages from some kind of disrupting events, such as a flood: ecosystem services would be crucial to regulate the climate and meteorological phenomena, supporting the restoration of soil fertility and thus of agricultural activities. In other words, ecosystems would provide the resources that are essential for the recovery of human activities, through processes that slowly but steadily develop and sustain the others. Nonetheless, a *remember interaction* might also descend from the anthropic *cycle* towards the natural processes *cycle*: this might happen when management activities clean up a riverbed area from obstructing debris. Here, anthropic activities would intervene in order to re-establish an unconstrained water body. On the other hand, the *revolt interaction* describes the escalating potential of destructive events: the collapse of a smaller *cycle* that might impact a larger *cycle*, forcing its collapse as well (Fig. 1.2b). For instance, when the flow rate of a river significantly increases under unusual weather conditions, a flood might affect the human settlement nearby. A flood might be considered as a *revolt interaction* prompting from an unusual event that rapidly evolves to impact and potentially destroy the human community. Similarly to the previous case, also the *revolt interaction* might prompt from the anthropic *cycle*, here inducing severe consequences on natural ecosystems. An exemplification of this kind might take place when human communities undergo deep changes in their structures, shifting a productive system that heavily exploits natural resources. The productive shift would destroy and reorganise the anthropic *cycle*, thus drawing also the stability of the natural ecosystem *cycle* into a crisis.

At this point, the discussion might explore some further facets, that diverge from the established panarchy framework, following some hints of the literature (see e.g. Redman & Kinzig, 2003). Here, the "reversed" *interactions* are formalised, as *reverse-remember* and *reverse-revolt*. The fundamental assumption is that the *reverse interactions* hold the same potential effect of the "original" ones, but they act on opposite directions: when the *remember* is a cascading force, the *reverse-remember* is an escalating driver, and when the *revolt* escalates, the *reverse-revolt* cascades (Fig. 1.3).



(a)



(b)

Fig. 1.3 - A Social-Ecological Panarchy with the three constituting adaptive cycles and the two reverse interactions, reverse-remember (a) and reverse-revolt (b), in the two possible configurations

In other words, a *reverse-remember interaction* represents the stabilising influence that a smaller *cycle* exerts on a larger, unstable *cycle* (Fig. 1.3a). This condition might occur when the physical processes of a river have consolidated a riverbed and a flooding area: this stability might inform the development path of a human settlement, in the sense that the human community would recognise hazardous areas and thence exclude them from development plans. On a different scale, the anthropic component might support the restoration of damaged natural areas. An attentive human community might indeed decide to place its resources in the compensation of occurred damages, thus contributing to the recovery of ecosystem services. On the contrary, the effects of a *reverse-revolt interaction* would assume the shape of a cascading disruption from a larger *cycle* to a smaller *cycle* (Fig. 1.3b). A collapse of ecosystem services would evidently cause severe issues to the human activities: for instance, the raise of water tables might alter the salinity of the soil, compromising its fertility and consequently the agricultural activities, possibly drastically. In a similar vein, the collapse of human facilities might impact the local physical processes, to the point of precluding the usual performance of natural functions: the collapse of a dam might destroy the downstream riverine area.

In general, it appears that the *adaptive cycles* might determine the development of each other *cycle*, at any scale and in any direction, both stabilising and jeopardising, both cascading and escalating through the hierarchy. In addition, these *interactions* are not necessarily isolated, but rather mutual feedbacks might reinforce each other in a synergic potential to further consolidate or destabilise the overall social-ecological system. In brief, this discussion confirms that the components of a complex social-ecological system might be more deeply interlaced than it might appear and that the impacts of the internal dynamics of an *adaptive cycle* might easily spill over the other *cycles*, potentially with unanticipated effects, at any scale of the hierarchy. Notably, a propagation of effects, either reinforcing or detrimental, "direct" or "reversed", might take place only if there is an "alignment of susceptibilities", that is if the components of the social-ecological system lie in the *phases* viable to be affected from the *interactions*.

1.2. Implications for disaster risk management

This observation strengthens the explanation of the *interactions* as a potential force that prompts from a *cycle* and influences the development of the other *cycles*, but has no effect until the appropriate conditions of susceptibility come into reality. This interpretation might be especially suggestive when approaching disaster dynamics. As previously mentioned, the social-ecological system adopted here focuses on a river basin, where floods represent a natural hazard that involve the natural processes *cycle* and might impact the anthropic *cycle*. Whether the disruptive effects occur or not, it depends significantly on the conditions of the anthropic *cycle*. A human community that is flexible and adapted to the riverine dynamics has a higher probability to successfully deal with floods, surviving the event possibly with little damage; conversely, a rigid and constrained human structure might be unable to absorb the impact, thence suffering severe damages. Where the river represents a hazard, human communities must be vulnerable and exposed to that hazard in order to suffer from the impact. In this sense, the (*revolt*) *interaction* represents the risk, here the flood risk, and its possibility of occurrence (Fig. 1.4).

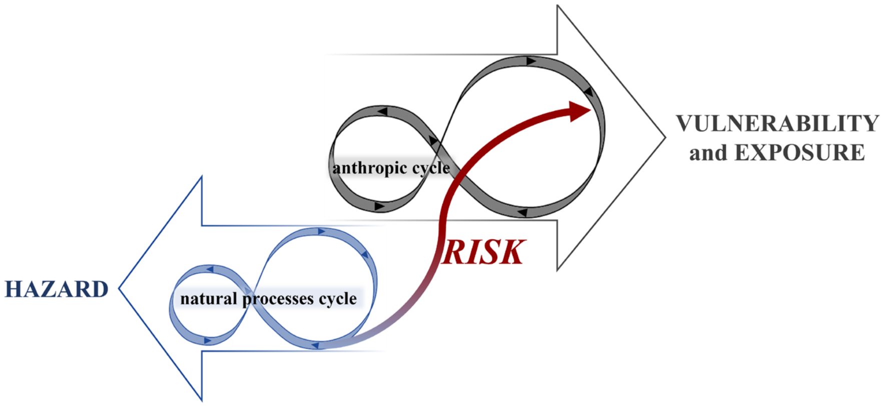


Fig. 1.4 - An example of the dynamics of a disaster in terms of hazard, vulnerability, exposure, and risk, within the framework of the Social-Ecological Panarchy

Nonetheless, the previous observations lead to the suggestion that this configuration is not the only possibility: as the *revolt interaction* might escalate as well as cascade through the levels of a panarchy, it derives a generalisation of the common adopted terminology. That is, within this framework, any *adaptive cycle* might be a threat to the others, but it becomes a hazard when it reaches the *phase* of release and following the state of collapse. From that *phase*, it has the potential to affect the other *cycles*, thus in that moment a risk is originated. Only if another *cycle* is vulnerable and exposed to the impact, the risk becomes a reality and a disaster takes place, inducing the collapse of the impacted *cycle*. Significantly, this dynamic is not scale-dependent, in the sense that a disaster might strike larger or smaller scales, depending on the "alignment of the stars" (Holling, 2001).

It follows that it might be especially significant to identify the premises for such alignment, that is the most sensible *phases* of the *adaptive cycle*.

When dealing with the effects of the *remember-type interaction*, it comes apparent that the crucial moments of the *cycle* lie in the *conservation* and in the *reorganisation phases* (Fig. 1.2a and Fig. 1.3a). If a component is stable enough, it might exert a supporting influence on another that is struggling to recover from a severe disruption. Nonetheless, these *phases* are located on the edge of some critical boundaries. Indeed, the *conservation phase* represents stability, but it also includes the bases of a collapse. That is, the equilibrium reached at the peak of development is inherently fragile and misleads into mistakenly relying on stability. As the *conservation phase* is the one susceptible to the impact of the *revolt-type interaction*, it represents a crucial nucleus of vulnerability.

In light of these considerations, it appears that the most desirable conditions for a component of a Social-Ecological Panarchy is to lie within the *fore-loop*. There, the support of the *remember-type interaction* leads to the engagement in new opportunities, to be experimented and explored. In this condition, it is possible to benefit from the innovations without toughening over a rigid architecture. Hence, it is suggested that, ideally, the components of a Social-Ecological Panarchy should remain in the *fore-loop*, not too forwards, in order to distance itself from the dangerous edge of a collapse, and not too backwards, in order to overcome the uncertainty of a new beginning. It means that the component remains flexible and adaptable, while enriching its potential in terms of assets and resources. It might be considered as a constant process of controlled destruction: creativity is encouraged, strategies are enacted, but internal restraints are destroyed before they could immobilise the component. From the *exploitation* to the *conservation*, then backwards along the *fore-loop*, destroying the constraints that would cause the fall in the *release phase*, and continuously reshaping the component. This does not mean that a disaster would never be able to affect the component: unprecedented events, feedbacks or external forces might still represent significant hazards. Nonetheless, promoting the permanence in the *fore-loop* encourages the mitigation of internal susceptibilities in order to reduce the disruptive potential of a disaster. It recalls the fundamental assumption recalled earlier: embracing change to preserve the overall integrity.

1.3. Reframing the cores of long-term development

The above discussion suggests that, rather than based on their effects (*remember-type* vs. *revolt-type*), *interactions* might be more significantly categorised based on their origin, that is depending on whether they prompt from the anthropic *cycle* (thus impacting the natural *cycles*), or, conversely, from the natural *cycles* (thus impacting the anthropic *cycle*) (Fig. 1.5 and Fig. 1.6).

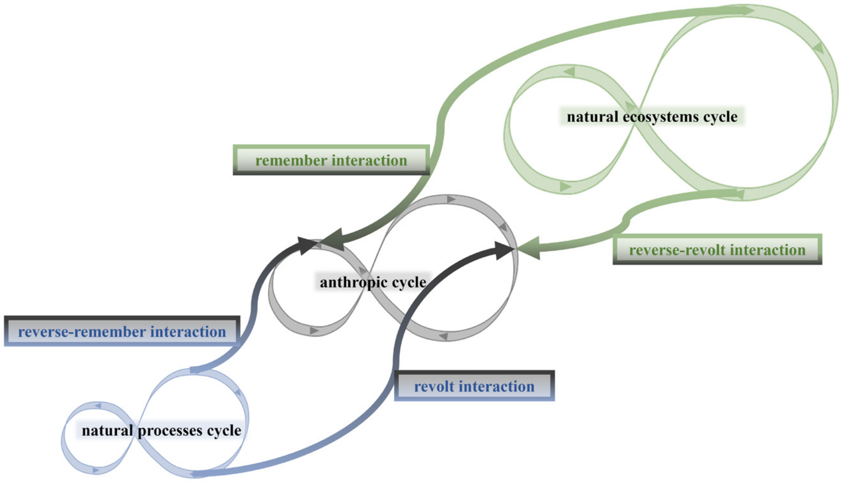


Fig. 1.5 - A Social-Ecological Panarchy and the possible interactions that start from the natural cycles and impact the anthropic cycle

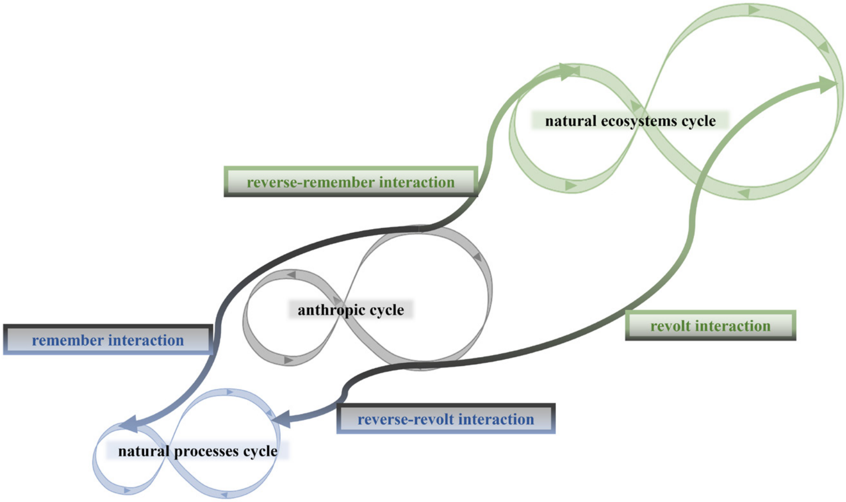


Fig. 1.6 - A Social-Ecological Panarchy and the possible interactions that start from the anthropic cycle and impact the natural cycles

A first combination appears when all the possible *interactions* converge on the anthropic *cycle* (originating from the natural *cycles*) (Fig. 1.5). The *remember interactions* suggest a human component that is responsive to the feedbacks of the ecosystems: it develops according to the limits (*reverse-remember*) and to the support (*remember*) provided by natural processes. On the other side, the *revolt interactions* warn against an anthropic *cycle* that is vulnerable and exposed to the impacts of extreme pressures stemming from the natural processes (*revolt*) and functions (*reverse-revolt*), that might cause the disruption of human structures. Overall, the stabilising forces still correspond to an advantageous stimulus, whereas the destabilising forces confirm their undesirable threat. Consequently, human communities should take on the effects of the *remember-type interaction*, while preventing the *revolt-type* from taking place. In this perspective, an effective development strategy should promote a sounder integration with the natural environment, respecting natural boundaries (e.g. promoting buildings codes to control urban development within flooding areas), while human communities would enhance their abilities to effectively deal with natural threats (e.g. implementing early-warning systems to allow locals to prepare for an extreme event). The focal concept is that human components of a social-ecological system should learn from the processes of the natural dynamics as well as they should strengthen in advance their coping capacities to severe hazards. This attitude is currently called *resilience*. Resilience is broadly defined as the capacity to learn from environmental processes in order to cope and adapt to external pressures preventing heavy damages. In this case, resilience deals with encouraging *remember-type interactions* and inhibiting *revolt-type interactions*, both converging on the anthropic *cycle*. In particular, *revolts* are prevented through the transformation of the anthropic cycle itself in terms of mitigating vulnerable and exposed conditions.

A second combination concerns *interactions* diverging from the anthropic *cycle* and affecting the natural *cycles* (Fig. 1.6). In this case, the human component might exert a force able to enrichen and support the development of natural systems (*remember-type*) or it might induce the destruction of natural equilibria (*revolt-type*). Once again, *remember-type interactions* lead to desirable, more stable conditions whereas the *revolt-type* prompts an undesirable, disruptive chain of events. Also in this case, *remember-type interactions* should be enhanced, while *revolt-type interactions* should be prevented. What differs in this configuration is that these requirements would translate in human activities that are devoted to restoring damaged or endangered natural systems (e.g. planting vegetation in riverine areas severely misused), while extreme effort would be placed on minimising the human impacts on natural components (e.g. promoting regulations against hazardous spills). That is, the human component of a social-ecological system would nurture environmental systems, while limiting as far as possible the detrimental effects of its own activities. This attitude is currently called *sustainability*. Sustainability represents the overall endeavour of human communities to promote a sound coexistence with the bio-physical systems, where flux of resources and information is bi-directional, addressing human needs without exceeding natural capacities. Once again, sustainability deals with encouraging *remember-type interactions* and inhibiting *revolt-type interactions*, but in this case they all diverge from the anthropic *cycle*. In particular, *revolts* are prevented through transforming the anthropic *cycle* in terms of mitigating hazardous conditions.

Together, the above considerations provide a specific perspective on the concepts of resilience and of sustainability. The panarchy modelling aligns with the definitions of resilience and of sustainability adopted in the wider literature, while introducing them in a unified, more complex system. Through the panarchy, these two *cores* eventually act within a same system. This allows to visualise the premises and consequences of both, and to evaluate their possible synergies or oppositions. In a few words, the proposed model has the potential to comprehend an integration of these domains. Although it is a qualitative representation, a Social-Ecological Panarchy might provide an integrated starting point for further discussions on the combination of disaster risk reduction approaches and environmental-driven strategies.

Some additional observations appear relevant. For instance, resilience and sustainability seemingly rely in a similar way on the *interactions*, as both encourage the consolidating *remember-type interactions* and oppose the destabilising *revolt-type interactions*. As mentioned, the difference lies in the origin and direction of impact of the *interactions* concerned by either resilience or sustainability approaches. Basically, this model confirms that human component should devise a development path that pursues an equilibrium between furthering its own progress and acknowledging natural boundaries. In particular, given the non-linear, mutual feedbacks that take place within a Social-Ecological Panarchy, one *core* should not prevail on the other. Both are necessary, but alone they are not sufficient. This leads to the assumption of resilience and of sustainability as *cores*, equally fundamental: the complex system cannot persist in the long period if failing to address either of them.

The need for a balance between the *resilience* and the *sustainability cores* recalls an unstable equilibrium already mentioned before, that is the fluctuation along the *fore-loop* as the most desirable state for an *adaptive cycle*. Here, the *anthropic cycle* would be transforming its structure by implementing the information from the natural components (*exploitation phase*, converging *remember-type interaction*), while supporting the natural components (*conservation phase*, diverging *remember-type interaction*). At the same time, rigidities would not be allowed to accumulate, in order to prevent the trigger of any kind of destructive force (*conservation phase*, converging and diverging *revolt-type interaction)*. Once more, the exploration of the *resilience* and *sustainability cores* supports the need for an approach funded on a continuous, transformative adaptation of the human components to the surrounding environment. Notably, this approach would also limit the occurrence of an "alignment of susceptibilities". In particular, rather that minimising risk through the control of natural processes, that has often turned into unanticipated detrimental consequences, risk is reduced by properly acting on human communities.

It might be interesting to observe that in this way neither resilience nor sustainability are optimised: it is a compromise between these two tendencies, to recognise and boost synergies. It is also notable that this does not mean that collapses would not be able to affect the anthropic *cycle* at all: it is more of a "*plan for the expected, prepare for the unexpected*" approach. It means that any possible effort should be put to prevent losses and damages, while accepting that when uncertainties exceed experience and anticipation, inevitable events might still take place. The point here is not to reject change: the idea is to encourage "*manageable destructions*" that allow the changes needed to remain in *fore-loop* as long as possible, until the worst will happen. The Social-Ecological Panarchy acknowledges this possibility and provides a framework to guide a renovated development endeavour.

At this point it might be relevant to shift from conceptual heuristics to an explanatory effort by means of an operative approach. Consequently, the following paragraphs will outline appropriate assumptions and hypotheses to apply the perspective of the Social-Ecological Panarchy to the issues concerning the disaster resilience and environmental sustainability of locales.

2. *Assumptions, objective, hypothesis and research questions*

Communities develop in a constant exchange with the natural ecosystems. Information, resources and energy flow in multiple directions and scales, pervading the whole social-ecological system. As a consequence, when addressing the question of survivability of human and natural components, acknowledgement has been gathering around the resolution not to neglect either of them, but rather to comprehend both urgencies within a common perspective. In brief, there is a common call to establish a sound coexistence with natural ecosystems. Nevertheless, such an endeavour requires a heuristic able to depict complex, non-linear dynamics.

The primary *objective* of this study is to further the understanding of human-nature interactions and of the consequences on the survivability of the overall social-ecological system. To this end, the panarchy model was adapted in a Social-Ecological Panarchy to reinterpret the discourse concerning disaster resilience and environmental sustainability. It was possible to delineate the possible behavioural trajectories of the components of the social-ecological system and to identify the most desirable conditions for the overall system.

In light of these considerations, an overarching *hypothesis* emerged:

The most desirable condition of the adaptive cycle (fore-loop) of the social-ecological system corresponds to a condition of high levels of disaster resilience and of environmental sustainability.

In other words, the demands to advance towards more resilient and more sustainable communities might be fulfilled if those communities promote a constant renovation and co-adaptation, that is, if they lie in the *fore-loop* of their *adaptive cycle*. A social-ecological system might consolidate its survivability in the long period only if all of its components move along their *fore-loop*.

Thence, it becomes relevant to further examine local social-ecological systems, identifying the components and assessing their condition of resilience and of sustainability, to draw some insights on the overall conditions of the social-ecological system. In particular, some research questions arise.

First, *how to assess resilience and sustainability? How to combine the levels of resilience and of sustainability? Is it possible to predict it?*

The panarchy model and the Social-Ecological Panarchy in particular provided a conceptual foundation for this study, but at this point it is necessary to take a step further and design an operative research framework. Although the interpretation of the local processes is essential, further understanding and managing social-ecological dynamics require quantitative tools. Possibly, it would be meaningful to hold a potentially predictive tool, so that trends could be anticipated.

Second, *what is the level of resilience and sustainability of the components of a social-ecological system?*

The mentioned quantitative tool should be applied to appropriate case studies, tailoring the assessment framework to the locales.

Third, w*hat is the tendency among those communities?*

The assessment would deliver the conditions of resilience and sustainability of each system component. Apart from investigating the reasons behind potential local differences, it would be relevant to recognise the position occupied by each component within their *adaptive cycle*, and especially the distance from the *fore-loop*.

Fourth, *what is the overall condition of the social-ecological system?*

Assessed the conditions of the components, it is significant to recompose the overall hierarchy and evaluate the conditions of the Social-Ecological Panarchy, especially looking for possible geographies of "panarchical behaviour". In other words, it would be relevant to observe the conditions of the overall system and possibly detect the role of place in determining the distribution of the positions of the components within the *adaptive cycle*.

The following paragraphs will introduce the methodological framework designed as an attempt to associate a quantitative dimension to the Social-Ecological Panarchy. Next, the proposed methodology will be applied to two case studies (i.e. Marche region, Italy, and Hokkaidō Prefecture, Japan) and the outcomes discussed extensively. Nevertheless, it is acknowledged here that these considerations concern only part of the issue. Indeed, the outlined quantitative assessment is not able to effectively account for the needs, ambitions and beliefs of people, that are in truth pivotal in drawing development paths. Accordingly, the last part of this study will attempt to address these arguments.

PART II – Quantitative assessment

3. *Literature review: resilience and sustainability assessments*

In order to navigate the wealth of methodologies proposed in the literature to assess resilience and sustainability, it is beneficial to settle some guiding principles. The previous research questions suggest some focal requirements:

a. Quantification of resilience and of sustainability
b. Use of objective indicators
c. Inclusion of disaster-related measures
d. Combination of resilience and sustainability, maintaining an equal weight

These points could be summarised as the need for a quantitative assessment methodology that employs variables collected through objective processes and related to disastrous events, in order to combine and balance resilience and sustainability. Unfortunately, to the knowledge of the author, such a methodology is yet to be comprehensively developed. Nonetheless, a manifold of studies has been developed and the most significant to the present discourse will be briefly discussed. Two different sections will treat resilience and sustainability, though a preliminary introduction will clarify why such a strong focus is put on the quantification of the *resilience* and *sustainability cores.*

3.1. Rationale for objective indicators

An indicator is a tool, able to represent a certain aspect of a multidimensional problem in certain point in time and space. When multiple indicators are collected, they can be combined to form a composite indicator, otherwise known as an index, that is able to condense the numerous details into one statement. This property is rather advantageous, as an index results more manageable and immediate to comprehend compared to single values, while retaining all the information provided by the partial indicators (OECD, 2008).

It might be relevant to discuss how the resilience and sustainability discourse would benefit from the development of indicators and indices. One of the major concerns is related to the multi-dimensionality of resilience and of sustainability, as already discussed here and in the literature (Cutter et al., 2008; Diaz-Balteiro et al., 2017; Ju, 2017). Notably, such complexity cannot but increase when the two *cores* are considered at the same time, as in this case. Thence, it is essential to employ a tool that is able to compound such a scattered picture into a single output. At the same time, each and every component of both resilience and sustainability represent a specific feature, that should not be lost (Linkov, Eisenberg, Bates, et al., 2013). In addition, the possibility regularly evaluate indicators, following the related trends both spatially and temporally, of particularly importance for both *cores* (Ju, 2017; Sahely et al., 2005), as they present a dynamic rather than a static nature. Furthermore, indicators can play an substantial role for the local governance, as they can inform decision making processes, consolidating the scientific base upon which policies are built (Ju, 2017). Along these lines, such tools can also guide the identification of priorities, in terms of both actions to implement and areas to involve (Cai et al., 2018). Eventually, indicators and indices might be employed in follow-up activities to monitor the performance of adopted measures and their impact on the system (González et al., 2018).

In light of these considerations, the use of indicators and indices appears justified within the present framework, hence the discussion will move to the assessment of resilience and then of sustainability.

3.2. Assessment of resilience

3.2.1. *Preliminary considerations*

One of the recurrent questions through the literature is rather paradigmatic: “Resilience of what to what?” (Carpenter et al., 2001). It was originally introduced to highlight how securing the resilience of a specific system in a specific point in time might come at the expense of the stability of other systems, in other times. In brief, when discussing and evaluating resilience it is important to keep in mind that effects, both positive and negative, might be transferred through temporal and spatial scales. This also suggests that resilience assessment tools should always clearly state the object of their interest since the very beginning, as well as both the time and the area of analysis.

At the same time, research efforts have engaged in the qualification of resilience. Not only many definitions of resilience exist, but many different labels have been associated to resilience. Studies have appeared concerning social resilience (Adger, 2000; Fekete, 2018), community resilience (Cutter et al., 2014; L. Gunderson, 2010), urban resilience (Bertilsson et al., 2019; Meerow et al., 2016), just to cite a few. However, they all share some traits in common, that are the recognised fundamental properties of resilience. Along the narrative originally proposed by Holling (1973), resilience pertains 1. the entity of perturbation that a system can withstand maintaining the same structure and functions; 2. the ability to establish anew the parts of organisation lost; 3. the ability to retrieve and implement lessons for a sounder adaptation (Carpenter et al., 2001). In other words, such basic and pivotal features can be translated as the ability to 1. absorb, 2. recover and 3. learn. These tenets could be considered as *attributes* of resilience, as they represent specific assets that together create a resilient behaviour. Indeed, such paradigm is not new, but has been permeating the resilience discussion (Hosseini et al., 2016), despite some variations in terminology (Tab. 3.1).

Tab. 3.1 - Some examples of the attributes of resilience (absorb, recover, learn) in the literature

Reference	*Attributes*
(Resilience Alliance, n.d.)	"capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organization, learning and adaptation"
(Holling, 1973, p. 17)	"ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist"
(Walker et al., 2006, p. 2)	"capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity"
(Lhomme et al., 2013, p. 222)	"ability of a city to operate in a degraded mode (absorption capacity) and to recover its functions, despite the fact that some urban components are disrupted"
(Nan & Sansavini, 2017, p. 36)	"ability of the system to withstand a change or a disruptive event by reducing the initial negative impacts (absorptive cap- ability), by adapting itself to them (adaptive capability) and by recovering from them (restorative capability)"
(Chuang et al., 2018, p. 354)	"ability of a community to prepare and plan for, absorb, recover from, and adapt to adverse events in a timely and efficient manner, including the recovery and improvement of basic functions and structures of social systems"

At the same time, resilience can be expressed in a variety of fields, hence different *dimensions* of resilience can be recognised. That is, characteristics of resilience can be traced in many facets of a system. Similarly to *attributes*, some recurrent *dimensions* can be tracked throughout the common practice. Despite some terminology variations, the main *dimensions* of resilience can be generally identified as: 1. demographic, 2. social, 3. economic, 4. health, 5. infrastructural, 6. natural (Tab. 3.2).

Tab. 3.2 - Some examples of the dimensions (demographic, social, economic, health, infrastructural) of resilience in the literature

Reference	*Dimensions*
(Cutter et al., 2008)	ecological; social; economic; institutional; infrastructure; community competence
(Mayunga, 2009)	human; social; natural; physical; economic
(Joerin et al., 2014, p. 547)	physical; social; economic; institutional; natural
(Shim & Kim, 2015)	biophysical; built-environment; socio-economic
(Beccari, 2016, p. 3)	governance; education, research, awareness and knowledge; information and communication; culture and diversity; preparedness; response; protection; exposure, experience and impact severity; resources; health and well-being/ livelihood; economic; adaptive capacity; coping capacity; innovation and capital; infrastructure and technical
(Cutter, 2016)	economic; social; institutional; information/communication; infrastructure; environmental
(Toseroni et al., 2016)	social; economic; infrastructural; environmental; institutional
(Cai et al., 2018)	social; economic; institutional; infrastructure; community; environmental/ecological; other

Interestingly, even when concerning a human system, resilience is usually represented as encompassing a natural dimension, recognising the influence of the surrounding environment on human well-being. This is a further confirmation of the assumption that human systems exist within complex social-ecological systems, hence any human response can be understood and should be investigated only considering all the components of a social-ecological system, either human or not. Tab. 3.3 provides an overview of the synthesis of the *attributes* and *dimensions* of resilience.

Tab. 3.3 - Common attributes and dimensions of resilience

Resilience	
Attributes	*Dimensions*
(resilience is the ability to…)	(resilience is expressed as…)
absorb	demographic
recover	social
learn	economic
	health
	infrastructural
	natural

3.2.2. *Assessment methodologies*

It is here acknowledged that an in-depth analysis of the methodological approaches proposed in the literature goes beyond the scope of the present discussion. Rather, here the interest is in exploring methodologies commonly employed or particularly significant for their analytical process.

One of the most important model is the DROP (Disaster Resilience of Place) model (Cutter et al., 2008), that later evolved in the BRIC (Baseline Resilience Indicators for Communities) model (Cutter et al., 2014). These models share a quantification of resilience by means of indicators and have become a common reference. The DROP model proposes a complex framework to understand "natural disaster resilience" (Cutter et al., 2008). It acknowledges that human-environment interactions play a fundamental role both in triggering and in coping with a disaster, although the structure is willingly flexible enough to be adapted also to events not driven by natural forces. The framework encompasses two phases, one concerning the conditions that prelude to the disaster and one concerning what comes after the disaster, that is the way the disaster is dealt with. The BRIC model follows these assumptions, expanding the area of application from the community of the DROP model. The main objective is to evaluate the innate resilience of a system, in order to provide a reference to test policies and strategies against. Nevertheless, both models fail in comprehensively include environmental sustainability measures, although formally recognising the importance of environmental dynamics. Furthermore, such models have been criticised for lacking an empirical verification of their accuracy and reliability (Cai et al., 2018; Toseroni et al., 2016).

A further model that has gathered agreement and validation, that is the CDRF (Community Disaster Resilience Framework), inspired, among the others, from the DROP model (Mayunga, 2009). The CDRF intends to combine quantitative indicators that encompass two main components: community assets and the phases of the disaster management cycle. Such indicators are primarily based on the suggestions of the DROP model, and data is collected from statistical bureaus and similar relevant sources. Later, indicators are aggregated assuming equal weights. The preferred scale of implementation of the framework is the county level, to address the most common level at which mitigation and risk reduction measures are undertaken (Mayunga, 2009). Due to the focus on human communities, the CDRF purposely excludes natural assets, though recognising the importance of the natural environment on the development and resilience of human systems.

The above-mentioned models operate at the national, county or urban/community level, hence a last scale is missing, that is the municipal level. Additionally, although several case studies appear all around the globe, there are still few applications on the Italian area. Under these premises, an interesting work is the Comprehensive Disaster Resilience Index (CDRI) (Marzi et al., 2019), involving all the Italian municipalities. The process follows from the widespread practice of collecting quantitative indicators, mainly (though not only) from the data provided by the Italian National Statistical Office. The indicators are later aggregated, weighted, statistically elaborated and verified. The authors also underline the importance for a framework to be replicable in other contexts, and so does the Comprehensive Disaster Resilience Index. One of the major drawbacks of this methodology concerns how environmental indicators are included. In particular, such indicators are processed at the same level of the other socio-economic ones, hence suggesting that their value can be compensated by man-made capital. Indeed, this matter of compensation, or rather of substitutability, plays a fundamental role in the present discourse. Additionally, even though the indicators are selected to represent disaster resilience, measures of community behaviour in times of an extreme event are still not directly represented.

In this context, Toseroni proposed another example of modelling efforts applied to local Italian areas (Toseroni, 2017). Also in this case, indicators are employed, selected in order to represent the multifaceted characteristics of local communities, including aspects related to disaster risk. The overall outcome is the IIR (*Indice di Impatto Reale*, that is Real Impact Index), is a score, easy to be interpreted, that aims at highlighting strengths and weaknesses of a human system. Indeed, the IIR intends to assist local authorities in their commitment in reducing disaster risk, e.g. by identifying the areas that need to be thoroughly improved. Although the scope of this model is relevant, the methodology follows a quali-quantitative process. Furthermore, even though an analytical procedure (an AHP, Analytical Hierarchy Process) leads to the final index, experts are asked to express a preference among the different sub-groups of indicators. By doing so, the IIR introduces a relevant factor of arbitrariness that diverges from the present requisites, along with the absence of environmental evaluations.

There is a shared agreement over the need to include the knowledge of local communities in any framework (UNDRR, 2015), and in models as well, as proved by some of the above mentioned research efforts. The Resilience Matrix (RM) model proceeds in this direction, while also including clear references to the phases and management of a disaster (Fox-Lent et al., 2015; Linkov, Eisenberg, Bates, et al., 2013; Linkov, Eisenberg, Plourde, et al., 2013). The model is based on the engagement of local experts and laypeople all along the process, from identifying the disaster scenario, to recognising the critical functions, to selecting the appropriate metrics. The collected information is then structured within a matrix, relating the functions recognised as critical with the disaster cycle phases. Hence an analytical procedure eventually provides a quantitative score that allows to simplify the visualisation of resilience levels in the matrix. This tool is intended to assist the identification of the areas of disaster management that need to be improved, thus helping local authorities in furthering risk reduction. Evidently, the RM model is based on the involvement of local communities, meaning that local uniqueness is captured and that it is flexible enough to adapt to different locales. Unfortunately, this also inhibits the impossibility to standardise the procedure.

The RRM (Risk and Resilience Monitor) proposes a solution to such critical issue (González et al., 2018). Rather than considering wide areas that would blur the evaluation, local characteristics are captured by focusing on small scales, specifically a commune and an urban level. Quantitative indicators are collected from common official sources and elaborated to produce a sort of score. The outcome is especially valuable in terms of visual power. Indeed, the produced maps highly effective in representing the geographies of risk and resilience. In addition, the analysis underlines the role of spatial scales, as the RRM shows a significant variation whether computed for the urban or the commune area, as well as for urban areas of different dimensions. This is suggested to be of extreme relevance for local planners and it hints at the need to discuss the proper scale to assess resilience.

When addressing a specific risk, it is pivotal to consider the distinctive characteristics of the related hazard in order to identify the most appropriate boundaries for the study area. As previously discussed, a suitable level of assessment of flood risk might be the river basin, in particular a urban area developed within a river basin (Bertilsson et al., 2019). The quantitative assessment collects data concerning several dimensions, including measures related to the factors of flood risk, subsequently aggregating the indicators to produce the S-FResI (Spatialised Urban Flood Resilience Index). The S-FResI is intended to both assess present resilience and to estimate resilience under different scenarios of risk reduction. Furthermore, the S-FResI is conceived to return a spatial representation of the different levels of resilience within the study area, hence allowing an immediate understanding of the conditions within the borders of the river basin. Unfortunately, the conditions of the environment are not envisioned within this framework.

Similar objectives drive the RIM (Resilience Inference Measurement) model (Lam et al., 2016). This model aims to associate a different level of resilience to each geographical unit of the study area. Furthermore, the RIM model can be applied to different spatial, temporal and hazard contexts, without losing efficacy (Lam et al., 2016), as proved by the several implementations in different time, space and risk scenarios (Cai et al., 2016; Lam et al., 2016; K. Li, 2011; X. Li et al., 2016). The RIM model is based on quantitative indicators that go through a two-phase analytical process. The first phase is a cluster analysis of indicators directly related to the disaster and to the response showed during that disaster. The result consists in a grouping based on similar behaviour during disaster occurrence. The second phase is a discriminant analysis to identify the specific characteristics that can explain such behaviour; here, indicators are identified in the consolidated practice related to socio-economic and physical environment domains. This second phase represents also as a validation of the previous one, testing validity and internal consistency. Lastly, the discriminant analysis produces a function both assesses the present levels of resilience and intends to predict the evolution of such levels.

A last relevant study takes extensive advantage of spatial indicators to approach the question of resilience, focusing on a county/city level (Fekete, 2018). In this case, an index of resilience is not produced as indicators are purposely left disjointed. The relevance of this effort resides the objective, that is to evaluate the effect of different definitions of resilience over its assessment, and of the explanatory power of some quantitative indicators, specifically considering their spatial variation. Here, the relevance of the choice of indicators emerges, highlighting how few are enough to describe specific aspects of resilience. This also implies that the meaning attributed to resilience significantly affects its quantification and representation. Additionally, the study addresses the question of scale, as the author recommends considering narrowed evaluations.

In a few summarising words, the above-mentioned models propose different procedures to associate a numerical dimension to resilience, hence resilience might indeed be reasonably quantified, though a conclusive methodology could not be identified. Apart from quali-quantitative assessments, objective quantitative indicators have been implemented. Seemingly, integrating disaster-related variables is possible, also considering common socio-economic and physical variables along with disaster behaviour. It might be noteworthy that in this context the identification of the proper assessment scale assumes a major role and many studies involve small spatial units. At the same time, some efforts were spent also to estimate future conditions of resilience. At this point, the discussion might move towards the question of sustainability assessment.

3.3. Assessment of sustainability

3.3.1. *Preliminary considerations*

As the *sustainability core* exposes to the fullest the inter-relation between natural and human systems, it seems relevant to question how and what to measure, if either only characteristics of the environment or also human processes. In this case, Social-Ecological Panarchy model provides a guidance, especially in the definition of what is intended with "sustainability" within the present framework. In addition, the outcome of the investigation should mirror that of the resilience assessment previously discussed, in order to later allow the eventual integration of these two sides of the analysis.

To begin with, this *core* describes the ability of a human system to carry on its functions without hampering the survival of ecosystems. As a consequence, features related to both human activities and natural processes are needed to explain sustainability. At the same time, resilience has been previously defined through *attributes*, that represent the essence of resilience, along with *dimensions*, that represent the areas in which resilience is expressed. Accordingly, sustainability should be described by some *attributes* that represent a condition of the ecosystems that can be directly affected by anthropic activities or, conversely, characteristics of the anthropic system that can directly affect the ecosystems. Then, some *dimensions* should portray the various aspects representing a sustainable behaviour. That is, *dimensions* should comprise several features of both ecosystems and anthropic processes that are directly interrelated and can be proxies of a sound human-nature coexistence.

A final point of this preliminary discussion addresses an operative aspect of the methodological process. Before building a complex index, indicators undergo a process of normalisation and of standardisation. The eventual combination implies crucial questions on weights and aggregation. More precisely, the matter of weights concerns the relative importance among the indicators, while the aggregation procedure concerns substitutability among indicators (Gan et al., 2017). In other words, assigning different weights translates into scaling the relevance of each indicator compared to the others. As a consequence, the choice of applying equal weights affirms that the analysed entities (in this case resilience and sustainability) are equally important. At the same time, aggregation procedures establish whether and to what extent an indicator might compensate for the others. The choice of simple juxtaposition affirms that any feature of resilience cannot substitute a feature of sustainability, and *vice versa*.

In other words, these two choices respond to the underlying assumption of a "strong sustainability" approach. This concept was introduced in the early 1990s, when discussing the extent to which manmade capital might compensate for natural capital (Daly, 1995). It might be argued that human activities are able to produce assets that can indefinitely replace the lost natural resources ("weak sustainability"), or that human activities should develop within the boundaries set by natural systems, which are only partially substitutable by manmade capital ("strong sustainability") (Daly, 1995). In this perspective, the proposed methodology adopts the standpoint of "strong sustainability": the *attributes* and the *dimensions* of a *core* are not allowed to prevail on those of the other *core*. At the same time, the enhancement of each *core* is encouraged, provided that it does not hinder the other *core*.

3.3.2. *Assessment methodologies*

In analogy to the resilience case, an extensive review of the related literature is beyond the present scope. Rather, some relevant studies will be explored.

One of the most important refences is the Millennium Ecosystem Assessment, prompted by the United Nations Secretary in 2000. The major objective was to assess how variation in the ecosystems could affect human wellbeing, thus also informing conservation policies and sustainable use. Here, the acknowledgement of the profound mutual influence between humans and nature appears evident. A fundamental contribution relates to ecosystem functions and services (Millennium Ecosystem Assessment, 2003b). Ecosystem services represent the natural benefits that humans take advantage of in a social-ecological system. Four main categories of ecosystem services were identified: provisioning, regulating, cultural, supporting. Ecosystem functions, though are the physical processes that allow the performance of services, hence the provision of benefits (Burkhard & Maes, 2017). The Millennium Ecosystem Assessment suggests that ecosystem services (and functions) represent a multifaceted question that inevitably requires a multidimensional approach, although at the same time it reassures on the possibility to translate such complexity in quantitative terms (Millennium Ecosystem Assessment, 2003b). Furthermore, the Millennium Ecosystem Assessment and other studies (Morimoto, 2011) suggest that a measure of the ability of the ecosystems to perform functions and deliver services is represented by the inner biodiversity, especially with regard to functional redundancy. Basically, ecosystem wellbeing is related to a wide variety of species and processes, performing different roles, in some cases overlapping. Here the importance of integrity emerges, as, naturally, an ecosystem would consist of a certain assortment of species, constantly evolving and adapting, while human activities often hinder this equilibrium. In brief, integrity represents how much an ecosystem has been negatively affected by human interferences. In light of these considerations, the *attributes* of sustainability can be identified as the state of ecosystem services (1) and functions (2), along with their integrity (3).

This brief exploration also introduces a preliminary introduction to the *dimensions* of the *sustainability core*. The Millennium Ecosystem Assessment might offer some further guidance. When approaching the question of valuation, the focus is explicitly on the benefits provided by ecosystems and on the related economic value (Millennium Ecosystem Assessment, 2003a). At the same time, it is interesting to stress that the aim of the Millennium Ecosystem Assessment is to provide a base to comprehend the impact of different management regimes. It is also highlighted that even though some benefits might be effectively quantified in economic terms, some others, such as socio-cultural values, should rely on different approaches.

Stemming from this inspiration (and from the model of the Intergovernmental Panel on Climate Change, IPCC), in 2012 the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established. The aim of the IPBES is to assist evidence-based policymaking in enhancing biodiversity and ecosystem services and driving sustainable development as well as human wellbeing (Díaz, Demissew, Carabias, et al., 2015; Díaz, Demissew, Joly, et al., 2015). One of the most relevant outcomes of the IPBES efforts is a Conceptual Framework, that highlights the deep interplay among humans and nature; in particular, six main elements are recognised pivotal (Tab. 3.4): nature (i.e. biodiversity and ecosystems), nature's benefits to people (i.e. ecosystem goods and services), anthropogenic assets, indirect and direct drivers of change (among which institutions and anthropogenic drivers, respectively), and good quality of life (Díaz, Demissew, Carabias, et al., 2015; Díaz, Demissew, Joly, et al., 2015; IPBES, n.d.). Here, it is noteworthy the acknowledgement of the role of humans, both as drivers of change due to their actions and as stabilising forces for nature thanks to a sound governance system.

Furthermore, the fact that managing sustainability should account for ecosystems and their characteristics has found wide agreement (Berkes et al., 2003). In particular, it is affirmed that sustainability finds its expression in management activities that do not force natural systems over their thresholds, but rather nurture diversity, variability, and possibly redundancy, rejecting the present common trend of optimising resources. In terms of assessment, the authors suggest that while quantitative analysis holds a relevant role, qualitative approaches, intended to portray the overall functioning of a complex system, are indeed valuable and can be complementary to the others.

Sustainable management of ecosystems results fundamental also to the survivability of human systems (e.g. a city) under serious threats, such as climate changes. In particular, the discussion around the role of biodiversity and the importance of preserving it has gained momentum, to the point of advocating a critical role for biodiversity *per se* in human development and specifically in urban planning (Morimoto, 2011). At the same time, Morimoto (2011) invites for a constructive debate over long-term local and management issues, that would include questions about ecosystem services and, consequently, biodiversity. In other words, the development of an urban setting is once more entangled to the integrity and well-being of ecosystems.

The question of sustainability is not exempted from considerations concerning the role of scale. In particular, it has been remarked that sustainability should be considered as a pillar within land management, along with social and economic themes (Termorshuizen et al., 2007). Furthermore, it is advised that the effects of land use should be carefully evaluated in advance, as alterations to spatial patterns of human and natural areas might severely affect ecosystem services. It is also acknowledged that the quantification of the relation between ecosystem benefits and ecosystem characteristics is still missing reliable and agreed tools. Nonetheless, the role of biodiversity is reaffirmed, as it is highlighted that a functional connection with healthy ecosystems has already been proved, hence that might serve as a focus for further research developments.

The difficulty of identifying a causal relation between (human and natural) drivers of change and alterations of the ecosystems is a serious and well-documented problem (Janetos et al., 2005). This especially hinders assessment efforts, limiting a clear recognition of direct associations between ecosystems changes and ecosystem benefits. Nevertheless, also in this case biodiversity assumes a pivotal role. Indeed, drivers of biodiversity loss appear to be fairly well comprehended and they seem to mirror alterations of terrestrial and aquatic environments. Consequently, it appears reasonable to draw a relation between biodiversity and ecosystem services (Termorshuizen et al., 2007).

At the European level, several efforts have investigated the question of sustainability quantification, both at a national and at a local level. European countries have been evaluated and ranked through a core set of indicators, identified by the European Environment Agency (EEA, 2005).

The evaluation is focused on 10 main themes (Tab. 3.4) that comprise a total of 37 indicators. Such indicators are retrieved from public agencies (e.g. Eurostat, European Environment Agency, International Energy Agency) and are objective in nature. On the other hand, the main focus of the European Common Indicators (ECI) promoted by the European Commission (EC) are local communities, represented by either cities or municipalities (Ambiente Italia, 2003). In this case, ECI includes 10 basic indicators (Tab. 3.4). For each indicator, a headline indicator is identified and, depending on the kind of information needed, data is collected through a variety of means, both qualitative and quantitative. Interestingly, in both cases indicators envisage environmental issues along with human processes, hence suggesting that drivers of change (human activities) and their effects (environmental conditions) are complementary is defining the sustainability of a certain area.

In terms of scale, the national level is rather widespread, possibly due to the need of evaluating the efficacy of national and international policies. That is the rationale of the Environmental Performance Index (EPI) (Yale Center for Environmental Law and Policy et al., 2012), with the objective of reducing environmental pressures on human health and promoting ecosystem wellbeing along with a sound environmental management (NASA Socioeconomic Data and Applications Center (SEDAC), 2012). In this case, 22 relevant indicators are distributed into 10 policy domains (Tab. 3.4). Interestingly, the EPI is the evolution of the Environmental Sustainability Index (ESI), likewise developed by the Yale University and the Columbia University, in collaboration with the World Economic Forum and the Joint Research Centre. The ESI encompassed 21 indicators, collapsed into 5 dimensions of sustainability (Tab. 3.4); the parallel representation of natural and human features is clearly stated (Abayomi et al., 2011). At the same time, it is acknowledged here that several implementations and discussions have sparked around this tool, along with critical reviews aimed at furthering the discourse over sustainability quantification through indicators (Babcicky, 2013; Jha & Bhanu Murthy, 2003).

In spite of significant attention devoted to the national level, effort of downscaling might result more suitable to deal with issues such as water management. When paired with sustainability issues, the level of a river basin might be the most appropriate. The Watershed Sustainability Index (WSI) was developed to fill a gap of models in this domain (Chaves & Alipaz, 2007). The authors stress that sustainability assessments should not be constrained by political boundaries, but rather cover the area most suitable for the purpose of the assessment. At the same time, they acknowledge that sustainability is a multifaced problem, hence a multi-dimensional tool is crucial, encompassing both human and natural features of the system. Accordingly, the WSI envisages 4 main indicators that comprise a total of 5 pressure parameters (Tab. 3.4).

A further downscaling can reach the city level, increasingly relevant with the growing power of attraction of urban areas (Mori & Yamashita, 2015). The City Sustainability Index (CSI) establishes some pivotal, preliminary foundations for city sustainability assessments. Among these, it is strongly affirmed that sustainability should not be pursued (nor measured) accepting a compromise between the basic components, that are the physical, social and human capitals (Mori & Yamashita, 2015). In addition, the CSI recognises that cities are not independent nor isolated from the surrounding area, hence any sustainability assessment should account for limits not directly defined by the city borders and capacities. The methodological approach of the CSI is based on the maximisation indicators, that describe the assets and products yielded by the city, and constrain indicators, that address environmental and equity issues (Tab. 3.4).

Tab. 3.4 - Indicator frameworks of sustainability

Methodology	*Developer*	*Scale*	*Assessment structure*
IPBES Conceptual Framework	IPBES	(varies from global to local)	1. ecosystem goods and services 2. biodiversity and ecosystems 3. human wellbeing 4. anthropogenic assets 5. direct drivers of change (natural and anthropogenic) 6. indirect drivers of change (institutions and governance)
EEA core set of indicators	EEA	national	1. air pollution and ozone depletion 2. biodiversity 3. climate change 4. terrestrial 5. waste 6. water 7. agriculture 8. energy 9. transport 10. fisheries
European Common Indicators (ECI)	EC	local	1. citizens' satisfaction with the local community 2. local contribution to global climate change 3. local mobility and passenger transportation 4. availability of public open areas and services 5. quality of the air 6. children's journey to and from school 7. sustainable management of the local authority and local enterprises 8. noise pollution 9. sustainable land use 10. products promoting sustainability
Environmental Performance Index (EPI)	Yale University, Columbia	national	1. environmental burden of disease 2. air pollution (effects on human health) 3. water (effects on human health)

	University		4. air pollution (ecosystem effects) 5. water (ecosystem effects) 6. biodiversity and habitat 7. forestry 8. fisheries 9. agriculture 10. climate change
Environmental Sustainability Index (ESI)	Yale University, Columbia University	national	1. environmental systems 2. environmental stresses 3. human vulnerability 4. social and institutional capacity 5. global stewardship
Watershed Sustainability Index (WSI)	(Chaves & Alipaz, 2007)	local	1. hydrology 2. environment 3. life 4. policy issues
City Sustainability Index (CSI)	(Mori & Yamashita, 2015)	local	1. maximisation indicators (assets and products) 2. constrain indicators (environmental and equity issues)

At this point, it might be significant to recollect the main concepts developed in the above discussion. Indeed, the investigation was intended to identify the *attributes* and *dimensions* of sustainability. The brief examination revealed the pivotal role played by ecosystem services, the physical processes that yield them and the integrity of the equilibria that grants these functions. Consequently, the *attributes* of sustainability can be overall identified as: 1. services; 2. functions; 3. integrity (Tab. 3.5). In other words, when studying a social-ecological system, the essence of sustainability is represented by a natural system that is able to soundly perform functions that deliver consistent benefits, profiting from an integrity granted by the human system.

At the same time, these considerations are echoed in the assessment frameworks. All the methodologies tend to include indicators related to the state of the environment, in some cases also encompassing the physical processes that are performed. However, ecosystems are evaluated also in terms of the effects suffered from external pressures. Indicators generally tend to portray the human component that coexist and interact with the natural one, spanning from political and productive facets to environmental awareness and local vulnerabilities. Hence, it is possible to identify some overarching *dimensions* of sustainability: 1. ecosystem integrity; 2. ecosystem benefits; 3. physical processes state; 4. external pressures; 5. human vulnerabilities (Tab. 3.5). In other words, sustainable characteristics of a social-ecological system can be traced in the richness of the provided services and benefits; the physical processes should proceed as much unaltered as possible and external drivers of change should be monitored. At the same time, a sustainable management is deemed possible only if the human system is stable and environmentally aware.

Tab. 3.5 - Attributes and dimensions of sustainability

Sustainability	
Attributes	*Dimensions*
(sustainability is the defined through ecosystem...)	(sustainability is expressed through…)
services	ecosystem integrity
functions	ecosystem benefits
integrity	physical processes state
	external pressures
	human vulnerabilities

3.4. Viable indicators for a quantitative assessment

Some closing remarks briefly address the matter of operative assessment. Indeed, the methodologies discussed above and the many others that have been proposed in the literature provide a further fundamental element for the present discussion, that is a set of the most common quantitative indicators. It is beyond the scope of this section to comprehensively recall such collection, though some observations can still be gathered.

To begin with, it appears that some themes are highly consolidated, as for instance the distribution, educational attainment and employment are recurrent in the resilience discourse (see e.g. Cai et al., 2016; Cutter et al., 2014; Joerin et al., 2014; Lam et al., 2016; X. Li et al., 2016; Marzi et al., 2019; Morrow, 2008; Shim & Kim, 2015), as much as species diversity, tree cover loss and nutrients in freshwaters are for the sustainability discourse (see e.g. Babcicky, 2013; Chaves & Alipaz, 2007; EEA, 2005; IPBES, n.d.; Janetos et al., 2005; Millennium Ecosystem Assessment, 2003b; Morimoto, 2011; Termorshuizen et al., 2007; Wendling et al., 2018).

Secondly, it might be noteworthy that in many cases indicators have been tailored to the specific study area, accounting for relevant policies or local trends. In these cases, transferability of indicators should be carefully evaluated and possibly amended, in case of need.

Lastly, though not directly appliable, indicators might still pinpoint issues that deemed significant to be considered. Such is also the case for indicators that might not be particularly common, but that could hint at relevant processes to the local sustainability.

Altogether, these observations contribute to the design of a novel assessment methodology to be introduced in the following paragraphs.

4. Quantitative methodology

4.1. A Combined Assessment of Resilience and Sustainability (CAReS)

The methodology herein proposed can be considered a Combined Assessment of Resilience and Sustainability (CAReS). This methodology is intended to be applied to a social-ecological system. Here, the units of analysis are subdivisions (*sub-units*) of the system (e.g. the municipalities are the sub-units of a region). The overarching structure comprises two lines of analysis, one per each *resilience* and *sustainability cores*. Both analytical lines follow the same process, use suitable indicators and are independent from the other; the results are paired only at the end, to obtain a final common output.

The first phase of the process might be considered a *classification* endeavour. The aim is to aggregate the *sub-units* based on their behaviour in the event of a disaster. The indicators used in this phase refer to the *attributes* of the *cores*. The procedure applied is a cluster analysis. When pairing the results for the *cores*, the "Resilience and sustainability level" emerges.

The second phase of the analytical process might be considered a *characterisation* endeavour. The aim is to trace the features that explain a specific behaviour of the *sub-units* in the event of a disaster. The indicators used in this phase refer to the *dimensions* of the *cores*. The procedure applied is a discriminant analysis, based on the grouping provided by the previous cluster analysis. When pairing the results for the *cores*, the "Predictive function of the resilience and sustainability level" emerges.

In the following paragraphs these two phases will be thoroughly discussed. Before that, it is important to define the leading principles of the analysis. Stemming from the available literature and adjusted to the present framework, the *attributes* and *dimensions* adopted here are presented in Tab. 4.1.

Tab. 4.1 - The attributes and the dimensions per each core of the CAReS methodology

Core	*Attributes*	*Dimensions*
resilience	absorb	demographic
	recover	social
	learn	economic
		health
		infrastructural
sustainability	services	ecosystem integrity
	functions	ecosystem benefits
	integrity	physical processes state
		external pressures

At this point, the overarching, methodological structure can be visualised, highlighting the centrality of the disaster theme (Fig. 4.1).

The structure, organised over two major phases and employing different kind of quantitative indicators, was inspired by the RIM model (Cai et al., 2016; Lam et al., 2016; K. Li, 2011; X. Li et al., 2016), although here the conceptual framework is provided by the Social-Ecological Panarchy model. Also the meaning of the indicators and their distribution between the two analytical phases came from the RIM model. Nevertheless, especially for the second phase of analysis, the choice of the indicators is primarily based on the research performed by Cutter and colleagues (Cutter, 2016; Cutter et al., 2008, 2014) for the resilience theme, and on the narratives of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2003b, 2003a), for the sustainability discussion.

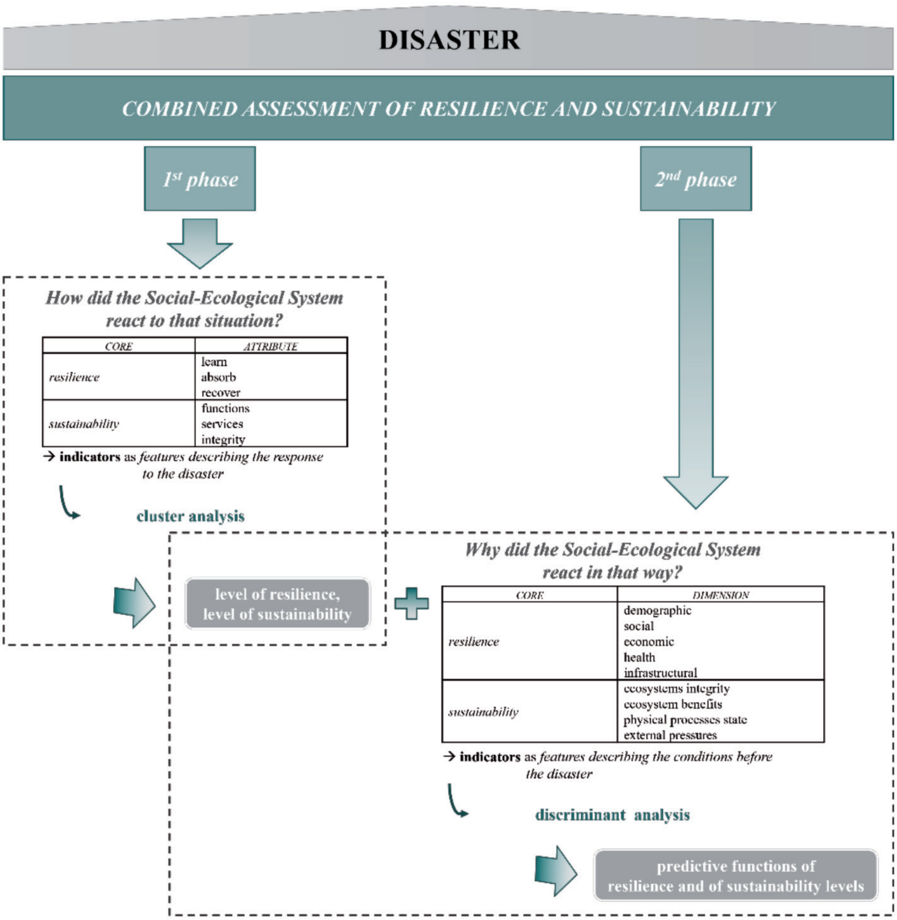


Fig. 4.1 - Structure of the proposed CAReS methodology

4.1.1. *Classification – A matter of cluster analysis*

The first phase of the proposed methodology aims to group the *sub-units* of the social-ecological system based on their behaviour in the event of a disaster. In this sense the first phase operates a classification, that is to allocate the *sub-units* in different classes according to their response to a disaster. Eventually, each class would correspond to a different level of resilience or of sustainability. For this purpose, the more suitable statistical technique is the cluster analysis.

Actually, the term "cluster analysis" refers to a set of algorithms. As an extensive examination of these techniques can already be found in the literature, here only the most relevant aspects will be briefly discussed. In particular, clustering algorithms classify items (here, *sub-units*) by means of variables (here, indicators associated to the *attributes*) measuring the relative similarity. Such similarity is treated as a distance: the closer the items are, the more similar they are, thence the higher probability of belonging to the same cluster (Johnson & Wichern, 2007). In the present case, the Euclidean distance is adopted, being recognised as the "truest" possible distance between two items (Johnson & Wichern, 2007).

Broadly, the major difference among clustering algorithms is between hierarchical and non-hierarchical techniques. Hierarchical techniques reveal all the possible clusters, either agglomerating or dividing the items. Consequently, as the procedure progresses, it is impossible to move misplaced item. In case of non-hierarchical methods, the items are arranged in a pre-set number of clusters. The process pairs the items, evaluates their distance and assigns them to a cluster. This allocation affects the position of the centre of the cluster, called centroid, that is progressively re-calculated. When another item is considered and the cycle repeated, the recalculation of the centroid allows to re-evaluate the allocation of each item. Eventually, reallocations are performed until the clustering is rather stable. In order to take advantage of the respective strengths, while compensating the other weaknesses, the methodology proposed here combines such different clustering techniques.

Hence, the proposed analytical process encompasses two clustering techniques, that is a preliminary hierarchical technique, followed by a non-hierarchical one. This mixed clustering procedure intends to first identify a tentative clustering structure, that is refined in the second step. In the first step the Ward's method is adopted, while the k-means is employed in the second step. The Ward's method is a hierarchical technique especially appreciated for limiting at most the loss of information when groups are formed (Johnson & Wichern, 2007). Furthermore, in spite of belonging to the hierarchical methods, the Ward's clustering technique is particularly similar to non-hierarchical techniques, to the point of being considered as an anticipation of the latter (Johnson & Wichern, 2007). Consequently, this method seems to optimise some criterions when assigning items to a given number of clusters (Johnson & Wichern, 2007). At the same time, the k-means is one the most common techniques among the non-hierarchical ones (Johnson & Wichern, 2007). A major weakness of the k-means method is it high sensitivity to the initial set of clusters or centroids, hence the introduction of the previous Ward's analysis.

By the end of the overall clustering procedure, each cluster has a stable centroid, and each centroid is associated with a set of different values, referred to the *attributes*. As a consequence, the comparison among such values (associated to the centroids) allows to identify a sounder or poorer behaviour of each cluster. In other words, each cluster corresponds to a different level of resilience and a different level of sustainability. Eventually, by juxtaposing those levels, each s*ub-unit* would own a combined level of resilience and sustainability. Given the complexity of the mentioned comparison among clusters, it is here assumed more convenient to limit the number of clusters, thus of levels. Hence, in this case, three (high – medium – low) levels of resilience and of sustainability are considered. Consequently, nine possible combined levels of resilience and sustainability are admitted (Tab. 4.2).

Tab. 4.2 - Possible combined levels of resilience and sustainability resulting from the first phase the proposed methodology

	High (H) to Low (L) level of Resilience (R)		
High (H) to Low (L) Level of Sustainability (S)	HR-HS	MR-HS	LR-HS
	HR-MS	MR-MS	LR-MS
	HR-LS	MR-LS	LR-LS

Notably, the proposed methodology is rooted in the framework of the Social-Ecological Panarchy. At this point it might be relevant to associate the levels of resilience and sustainability to the *phases* of the (anthropic) *adaptive cycle*. This would allow to identify the position of each *sub-unit* in the related *adaptive cycle*. To the knowledge of the author there is not such an attempt in the existing literature, hence the proposed association of levels of resilience and sustainability to the *phases* of the *adaptive cycle* can be considered a novel contribution to the common discourse (Fig. 4.2).

To begin with, the highest levels of resilience and sustainability (HR-HS) might be considered. In this case, the overarching hypothesis of this study guides the association to the *fore-loop*, as it affirms that there lie the most desirable conditions. Then, by moving forwards along the *fore-loop*, the *sub-unit* is optimising the use of resources and assets, while also building up rigidities, namely it is approaching the critical threshold before the eventual collapse. Here, it might be considered that the level of

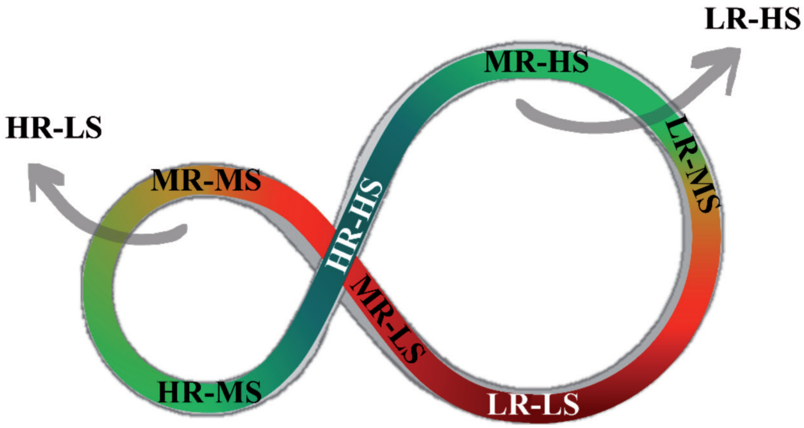


Fig. 4.2 - Levels (low L, medium M, high H) of resilience (R) and of sustainability (S) associated to the phases of the adaptive cycle

sustainability remains high, because the *sub-unit* tends to conserve rather than to exploit capitals, whereas the level of resilience is declining, given the increasingly susceptible conditions (MR-HS). In a similar vein, the more the *sub-unit* progresses towards the *release phase*, the less resilient it becomes, while also its sustainable characteristics lose consistency, since survival needs might prevail over environmental care (LR-MS). Eventually, the collapse of the fundamental functions of a *sub-unit* would cause the minimisation of those levels (LR-LS). Later, the basic functions are slowly restored. The conditions within the *back-loop* are still highly susceptible, though the capacity to cope with external pressures is increasing; conversely, environmental issues might not be considered a priority of human processes (MR-LS). Nevertheless, once assets and structures are being consolidated, resources would be increasingly allocated to a more sustainable development (MR-MS). Even if the priority of the *sub-unit* might remain the consolidation of its internal processes (HR-MS), in time resources would be available to foster again a sounder coexistence with the environment (HR-HS). With this, the *cycle* is completed, being back in the *fore-loop*. Under such premises, the fluctuation along the *fore-loop* represents a domain closely surrounding the most desirable levels (HR-MS, HR-HS, MR-HS).

The previous discussion explains the majority of the combinations of the levels of resilience and sustainability. Two combinations are missing, those of the highest and lower levels (HR-LS and LR-HS). In this regard, it is possible to recall the *traps* identified in the first introduction of the panarchy theory. In particular, it might be argued the existence of a *resilience trap* (HR-LS) and of a *sustainability trap* (LR-HS). In the first case (HR-LS), the *sub-unit* is recovering its fundamental functions, maximising the efforts to build back a stable and responsive structure. In this effort, though, environmental issues are scarcely addressed. Hence, the undertaken development path diverges from the *cycle* presented here, because though the *sub-unit* might be enhancing the overall capacity to face adverse events, it is compromising its long-term survivability by dismissing the other *core*. Analogously, if capacities were optimised to reduce to the broadest extent the human impact on the environment, it might turn detrimental for the flexibility and adaptability of the *sub-unit* in case of adverse events (LR-HS). For instance, over-optimised processes that lack of minimum redundancy might not be able to deal with unexpected events. Also in this case, the overall survivability of the system would be compromised, hence the development path moves away from the *adaptive cycle* presented here. Remarkably, these observations suggest that maximising either of the two *cores* might compromise the other. Resilient strategies that dismiss environmental issues might induce fatal disequilibria in the environment in the long period, while sustainability strategies that underestimate human needs might limit human adaptability to change. This appears to confirm that such can be considered undesirable conditions and dangerous lock-ins, that is development *traps*.

At this point, the first phase of the proposed methodology is concluded. The process differentiated among the capacities of resilience and sustainability of the *sub-units* and provided the base for the second phase of the methodology.

4.1.2. *Characterisation – A matter of discriminant analysis*

The second phase of the proposed methodology aims at identifying which features are more effective in determining the behaviour shown during a disaster. In other words, this second phase should reveal a correspondence between the levels of resilience and of sustainability (expressed through the clusters, i.e. categorical data) and the indicators of the *dimensions* (i.e. continuous data) (Tab. 4.1). In this sense, the analysis operates a characterisation, as the characteristics of the *sub-units* are examined in order to find the best explanation to the previous clusters.

The multivariate analysis is especially suitable to pursue such an objective. Among the available techniques, the discriminant analysis might be especially appropriate. Indeed, this technique not only processes categorical data as dependent variables and continuous data as independent variables, but it also seeks to explain and predict the dependent variables by arranging a function with the independent variables. In other words, the objective is to design a linear combination of independent variables that best describe the difference between the dependent variables. Such linear combinations are called discriminant functions (Eq. 1):

$$Y_{jk} = a + w_1 x_{1k} + w_2 x_{2k} + \cdots + w_n x_{nk} \qquad (1)$$

where Y_{jk} is the score of the *j*-th discriminant function for the *k*-th unit of analysis, α is an adimensional coefficient, $w_n x_{nk}$ is the product of the *n*-th *w* weight with the *n*-th *x* variable for the *k*-th unit of analysis. Interestingly, the discriminant analysis can both discriminate and classify items. This means that one technique can both optimise the differentiation among groups of items, and assign an item to a group (Johnson & Wichern, 2007). Furthermore, it is noteworthy that, in general terms, a plurality of discriminant functions is generated, the number of which being case-specific.

The discriminant analysis yields two valuable outcomes. On the one side, the discriminant function can evidence the most influencing indicators in determining the clusters. Consequently, if the analysis was to be applied again to the same case study, the range of indicators might be limited, in order to optimise such a resource-intensive process. On the other side, the discriminant function might simplify monitoring activities, as it allows to verify the cluster of each *sub-unit* (i.e. the level of resilience and sustainability) without performing a cluster analysis, that is a particularly significant advantage. Indeed, the cluster analysis relies on indicators that can be quantified only at the occurrence of a disaster, while the discriminant analysis would allow to estimate the same outcome bypassing the disaster occurrence. In other words, it is possible to estimate the levels of resilience and of sustainability through time without the direct reference to a disaster. In this way it is also possible overcome the static nature of other methodologies, that is a feature often criticised (Cai et al., 2018). Here, the assessment would be able to follow the potential changes in resilience and levels.

Apart from further applications, the discriminant analysis holds also a more operative value, as it provides a kind of validation of the methodology itself. Indeed, the clusters resulting from the first phase and the second phase might be compared: the more similar they result and the more robust is the overall analytical process (Cai et al., 2016). At the same time, the discriminant analysis supplies some internal tests to validate the soundness of the results, strengthening the reliability of the procedure.

Eventually, here the discriminant function takes the name of "Predictive function of the resilience and sustainability levels". In accordance with the overall framework divided into two analytical lines, this second phase provides a discriminant function per each *core*. Consequently, the predictive function of the resilience and sustainability levels is actually a system of functions, one for resilience (R) and one for sustainability (S), for every (k-th) *sub-unit* of the social-ecological system (Eq. 2).

$$\begin{cases} R_k = a + w_1 x_{1k} + w_2 x_{2k} + \cdots + w_n x_{nk} \\ S_k = b + v_1 z_{1k} + v_2 z_{2k} + \cdots + v_n z_{nk} \end{cases} \qquad (2)$$

At this point, the overall assessment procedure is completed. The following paragraphs move to its implementation on selected case studies.

5. *The case studies*

At this point, it is possible to implement the proposed methodology. To this end, two main points need to be clarified, that are the risk scenario and the geographical setting, especially in terms of related *sub-units*. These aspects are crucial, since they significantly influence the adaptation of the proposed methodology to the local conditions, specifically when selecting the appropriate indicators. Notably, the methodology was applied to two case studies, Marche region (Italy) and Hokkaidō Prefecture (Japan). Although more details will follow, it is here anticipated that these case studies were chosen in order to compare the process and outcomes of the analyses and thus identify common elements that define *resilience* and/or *sustainability*, or rather local conditions that play a prominent role in defining these *cores*. Furthermore, it may be relevant to note that in these cases the primary interest is to investigate the conditions of resilience and sustainability of the regions; municipalities are assumed as *sub-units* because they provide the smallest possible scale of internal variability.

5.1. The risk scenario

Social-ecological systems are subjected to a manifold of risks, sometimes even mutually reinforcing. As this is a first attempt to implement the proposed methodology, it appears necessary to simply such scenario, in order to keep the assessment problem manageable. Possibly, future developments will be able to consider more complex risk conditions.

In light of these considerations, the present study focused on flood risk. Among the others, floods represent an exceptionally severe threat for human communities. In 2021 and consistently on average during the last twenty years (2001-2020), floods have registered the highest number of disaster events and affected the highest proportion of population compared to all the other hazards, while also maintaining a sore toll in terms of life and economic losses (CRED, 2022).

Floods are projected to remain a global threat for the survivability of human and natural systems in the future, also due to the effects of climate change. Indeed, environmental changes will probably worsen the occurrence and the impacts of floods (IPCC, 2022), especially when a large part of the most vulnerable communities resides in floodplains and coastal areas, not to mention the common reliance on climate-sensitive sources (Huang-Lachmann & Lovett, 2016).

In general terms, human settlements represent some of the highest vulnerabilities, while also being pivotal to tackle flood risk. For instance, cities can play a key role in dealing with water-related risks (Patterson, 2018). While urbanisation is proceeding at a growing rate, European and Asian cities appear to recognise the threat related to floods, though not its full extent (Huang-Lachmann & Lovett, 2016). At the same time, well-managed green and rural areas provide efficient means to adapt to and manage flood-related events, while also supplying fundamental services and products (EEA, 2017; Mukherjee & Takara, 2018; Natuhara, 2013; Venema, 2009).

Though brief, the above discussion confirms flood risk as a significant and increasing threat for communities, at every geographical level and location.

5.2. Marche region

The Marche region represents the first case study. It lies on the eastern edge of central Italy, along the Adriatic Sea, surrounded by the Republic of San Marino and the Emilia-Romagna, Tuscany, Umbria, Lazio, Abruzzo regions (proceeding North to West to South) on the other sides (Fig. 5.1).

The region covers a rather limited area and the population is not particularly numerous (ISTAT, 2019), while the residential structure still retains some of the historical features, thus spreading similarly to a net throughout the region (Enciclopedia Treccani, n.d.) (Tab. 5.1). The 229 municipalities that compose the region are gathered into 5 provinces (Pesaro-Urbino, Ancona, Macerata, Fermo, Ascoli Piceno, from North to South), where the administrative centre is based in Ancona.

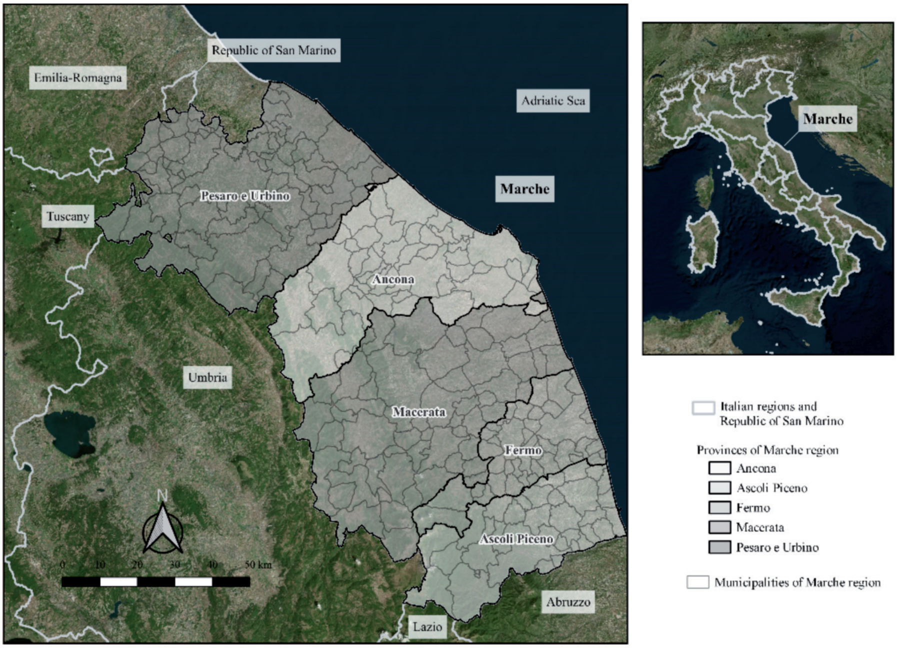


Fig. 5.1 - The Marche region and the related municipalities, the Adriatic Sea, the neighbouring regions and Republic of San Marino

Tab. 5.1 - Main characteristics of the Marche region as of 2018

	Area (km^2)	*Population (persons)*	*Population density (person/km^2)*	*Municipalities (number)*
Marche region	9 401	1 525 271	162.25	229

Source: adapted from ISTAT, 2019.

The characteristics of the Marche region are rather homogeneous, especially the physical features (Fig. 5.1). From West to East, mountains descends into smooth hills that cover a large part of the region (around 69%), until reaching the coastline: plains are almost absent, except for some narrow fluvial valleys (Gentilucci et al., 2019; Morri & Santolini, 2022). The climate results affected by these features: following the Köppen-Geiger climate classification, the climate highly varies within the temperate classes and transitioning to the continental class towards the mountains; in brief, it is possible to recognise distinct seasons, and precipitations are more frequent in the coldest months (Gentilucci et al., 2023). As a further consequence of the complex topography of the region, the hydrology results in common specific traits: torrential regimes and reduced courses along a West-East direction (Gentilucci et al., 2019; Morri & Santolini, 2022). The 30 river basins enclosed within the regional boundaries mainly follow the same direction, although some of them are shared with the neighbouring regions, hence in these cases their features as well as their management present some distinctive aspects (*Piano stralcio di bacino per l'Assetto Idrogeologico dei bacini di rilievo regionale (PAI) 21.01.2004*, 2004). Nevertheless, studies concerning flood risk have evidenced the general critical conditions of the river basins, as a high proportion (39%) of the area retains proved flooding potential (*Piano stralcio di bacino per l'Assetto Idrogeologico dei bacini di rilievo regionale (PAI) 21.01.2004*, 2004). Indeed, flooding events have marked the recent years. The database of the Regional Civil Protection offers an overview of the latest events (Regione Marche, n.d.-e), though those that prompted the declaration of the State of Emergency certainly hold particular relevance (Regione Marche, n.d.-c). It is possible to observe that severe flood events do not usually affect the overall region, but rather limited areas. This aspect is particularly relevant for the present methodology, given that the first phase of analysis aims at comparing disaster behaviour, hence it is necessary that all the municipalities faced a disaster event. Consequently, in the present study, the temporal span of analysis covers the years from 2011 to 2015. By doing so, the majority of the municipalities of the Marche region was involved at least once in an event severe enough to declare a State of Emergency (Tab. 5.2 and Tab. 5.3). In addition, the minimised time span allows to expect limited variations of the indicators during the concerned period.

In a few words, the Marche region has been shaped and is susceptible to floods, that represents a relevant regional risk. In this case, the Marche region embodies the studied social-ecological system, and the 229 municipalities constitute the *sub-units* of analysis. This assumption can be considered reasonable because the natural as well as the socio-economic characteristics of the Marche region are nearly homogeneous among the municipalities. The regional authority acts as an overarching management

Tab. 5.2 - Events considered in this case study and related number of affected municipalities, per year

Event		
Year	*Month*	*Number (and share) of affected municipalities*
2011	March	165 (72.05%)
2012	November	49 (21.40%)
2013	November-December	183 (79.91%)
2014	May	126 (55.02%)
2015	March	158 (69.00%)

Tab. 5.3 - Number and share of municipalities per number of events, in the period 2011-2015

	Number of events						
	0	1	2	3	4	5	*Total*
Number of municipalities	6	33	36	56	82	16	229
Share of municipalities	2.62%	14.41%	15.72%	24.45%	35.81%	6.99%	100%

body, setting the overall management policies later adjusted and enforced by mayors. In brief, the region can be considered as a sole social-ecological system that responds to a disaster, with locales expressed as municipalities. The temporal dimension spans from 2008 to 2018, centring on the years 2011-2015, in order to register the behaviour before, during and after the disaster events of the municipalities.

5.3. Hokkaidō Prefecture

The Hokkaidō Prefecture represents the second case study. It surrounded by Sea of Okhotsk, the Sea of Japan and the Pacific Ocean, and it represents the Northernmost border of Japan. The nearest Japanese Prefecture is Aomori, on the Honshū island, though the nearest mainland is part of the Russian Federation, a unique position compared to the other main islands of the Japanese archipelago (Fig. 5.2).

A premise appears necessary regarding the local toponymy. To begin with, the name "Hokkaidō" includes the suffix denoting its role as a Prefecture (道, *dō*, meaning "Circuit", to be precise), hence it is appropriate to use it without any further attachments. It is also acknowledged here that, in Japan, the lowest administrative levels might be cities (市, *shi*), towns (町, *chō* or *machi*) and villages (村, *mura*). In order to facilitate the discussion, here this administrative level will be simply referred to as "municipality", similarly to the Italian case study. Furthermore, for the sake of legibility, in the present discussion the transliteration (called *romaji*) of the Japanese toponymy is used, adapted from the official *furigana* toponymy (Japanese Government Statistics, n.d.-a). As a final remark, it is worth mentioning that the Kuril Islands are not included in the present study, because of their controversial administrative situation.

Hokkaidō is composed of 179 municipalities, where the capital city is based in Sapporo. The geographical extension of the region is rather significant, and even though the population of Hokkaidō is rather high in number, the mean population density remains low (Tab. 5.4).

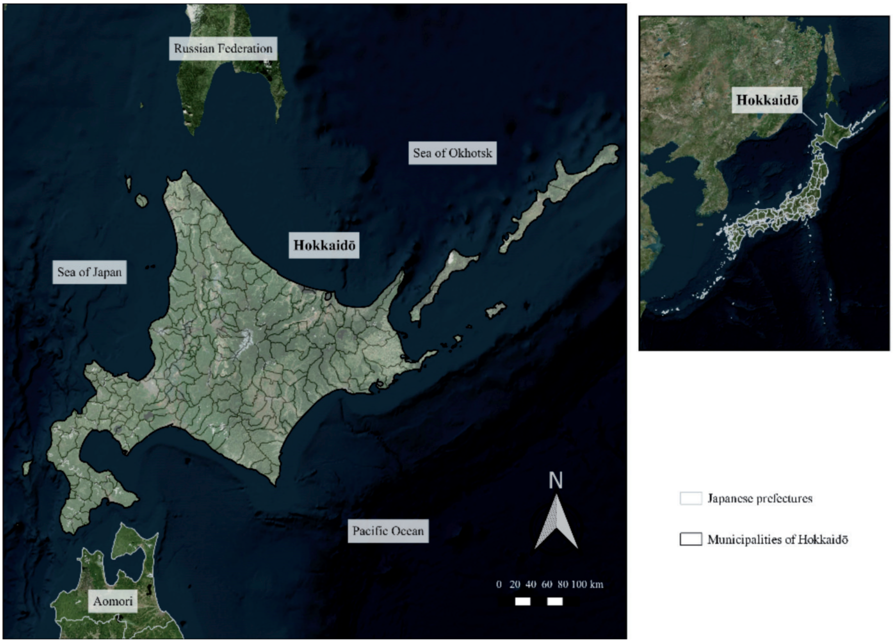


Fig. 5.2 - Hokkaidō and the related municipalities, the Sea of Okhotsk, the Sea of Japan, the Aomori Prefecture, and the Pacific Ocean

Tab. 5.4 - Main characteristics of Hokkaidō as of 2018

	Area (km^2)	*Population (persons)*	*Population density (person/ km^2)*	*Municipalities (number)*
Hokkaidō	83 424	5 286 000	63.36	179

Source: adapted from Japan Government of Statistics, n.d.

The climate of this Prefecture is affected by the position of the island: it mainly resembles the continental type, and even though it is possible to recognise four main seasons, there is not a rainy season and in the coldest months heavy snowing events might happen, especially on the western side (MLIT, n.d.-d). Hokkaidō is dominated by mountains and volcanoes, some of which are active, that align along a North-South direction and limit the plains to the coastal areas (Encyclopaedia Britannica, n.d.). As the rivers cross the region in an articulated and spread net, the development of Hokkaidō in the centuries has naturally integrated water bodies, their dynamics and their surrounding environments (MLIT, n.d.-e). Rivers are acknowledged as a threat, but also as a resource for local communities, both human and not (MLIT, n.d.-e). Hence, the strategies to promote a sound coexistence with water systems embrace a broader perspective, one that could encompass the rivers all along their course and the natural setting. In this perspective, floods are considered a part of the natural processes that characterise the region. During the Meiji Era (late 19th-early 20th century), the newly established Government resolved to promote Hokkaidō as a critical node for the progress of Japan as a whole, hence public infrastructures and private activities begun to flourish along with a steady and relevant increase of the local population (MLIT, n.d.-f). Around the same time, management activities concerning water-related hazards were prompted to secure the growing and expanding assets from the recurrent threats that flooding (MLIT, n.d.-g). This is especially relevant when the expansion of social and productive structures and infrastructures were concentrated in the lowland areas of riverine plains, hence the impact of floods could be particularly severe. Indeed, in recent years Hokkaidō has heavily suffered from flood events (MLIT, n.d.-c), often originated from particularly intense typhoons.

A recent flood that happened in 2016 represented one of the most serious events of the recent history. Between August 17 and 23, three different typhoons landed on Hokkaidō, followed by another only a week later (MLIT, n.d.-j). This resulted in an unprecedented condition, as three typhoons landing on Hokkaidō were never recorded before, and in some places the amount of precipitation corresponded to annual values (MLIT, n.d.-c). The overall Prefecture was impacted, with human communities severely affected, in terms of lives lost, heavy damages to private and public assets (MLIT, n.d.-j). Also economic activities were deeply affected. Since the Meiji Era, Hokkaidō prompted the development of agriculture, intended to benefit all Japan (MLIT, n.d.-j). The events of August 2016 caused vast damages to the primary sector of Hokkaidō, as food-related activities suffered from crop management to transportation, to processing lines, leaving Japan without one of the most important food suppliers (MLIT, n.d.-j). Similar cascading effects involved also other economic sectors (MLIT, n.d.-j). Nevertheless, these events prompted a raising awareness of the threat posed by floods, also recognised as worsening due to climate changes. The authorities endorsed the need for further mitigation measures, combined with innovative adaptation strategies, both structural and non-structural (MLIT, n.d.-c).

In brief, the topography of the region, along with the exposure to typhoons and other heavy rainfall events, make floods a recurrent and significant threat for Hokkaidō. This island is geographically isolated, as well as politically autonomous, and internally rather homogeneous. Consequently, Hokkaidō can be assumed as a social-ecological system, composed of the 179 municipalities that provide the *sub-units* of the analysis. In this case, the temporal dimension is centred on the year 2016, especially referring to the events happened in August. In an operative perspective, the time period considered spans from 2015 to 2017.

5.4. Marche vs. Hokkaidō

At this point, it might be possible to briefly compare some illustrative traits of the case studies (Tab. 5.5).

Tab. 5.5 - Main characteristics of Marche and Hokkaidō case studies

Feature	*Marche region*	*Hokkaidō*
Position	Central Italy (mainland)	North Japan (island)
Area extension (in km^2)	9 401	83 424
Population (people)	1 525 271	5 286 000
Topography	Predominantly mountains and hills; valleys limited to coastal areas; torrential regime of rivers	
Administrative status	Region	Prefecture
Number of municipalities	229	179
Time period	2008-2018	2015-2017
Flood period	2011-2015	2016
Number of events	5	4

It appears that, even though the case studies are different in extension of their area and population, they share some important traits. To begin with, the case studies share a complex morphology, characterised by mountains that almost abruptly descend towards the coasts. This morphology affects the characteristics of the respective rivers. The natural characteristics of the regions are especially valuable, as national, regional parks or other natural protection initiatives are common in both areas. Also, the case studies show similar climates, where the coldest months show the most significant rainfall and snowfall events. In general terms, flood events have always been part of the development of these areas. Nonetheless, floods tend to be rather localised in the Marche region, whereas the 2016 events of Hokkaidō impacted the overall Prefecture. The two regions show some similar traits also in socio-economic terms, as for instance, agriculture plays a prominent role in the local development along with tourism, although SMEs (Small and Medium Enterprises) and tertiary services are the cores of the economic activities (respectively for Marche and Hokkaidō).

In light of these considerations, it seems appropriate to apply the proposed methodology to these case studies. Marche region and Hokkaidō share features similar enough to allow for a comparison of the outcome of the analysis, yet different enough to possibly identify some drivers of local behaviour. Although it will be later discussed, it is important to mention here that the proposed methodology does not allow for the direct comparison of the results, as the evaluations in terms of resilience and sustainability do not have an absolute meaning, but they are relative among the municipalities of a single case study; for instance, it is not possible to tell if a municipality of Marche has a higher or lower resilience compared to a municipality of Hokkaidō. The aim of applying the methodology to two case studies is first and foremost to compare the overall performance of the quantitative assessment, identifying possible strengths or issues in adapting as well as operating it. Furthermore, common traits in terms of *resilience* and *sustainability* may emerge between the case studies, thus adding insights on the ongoing discussion on these *cores*. In this sense, the underlying differences of the socio-economic contexts may play a significant role, strengthening the possible outcomes. Notably, the different availability of data will likely influence the selection of the indicators and thus the application of the methodology, evidencing the practical phases of the analytical process that may need refinements and particular attention.

5.5. Tailoring the proposed methodology to the case studies

As previously suggested, the operationalisation of the methodological framework needs to adapt the rationale of *attributes* and *dimensions* of resilience and sustainability to the local characteristics. The basis of such adaptation is the wider literature build on the assessment of resilience and sustainability (Bagliani & Pietta, 2013; Cai et al., 2016, 2018; Chaves & Alipaz, 2007; Cutter, 2016; Cutter et al., 2008, 2014; Díaz, Demissew, Carabias, et al., 2015; Díaz, Demissew, Joly et al., 2015; EEA, 2005; European Commission & Directorate-General for Environment, 2000; Graziano & Rizzi, 2016; IPBES, n.d.; Joerin et al., 2014; Kadir, 2021; Mori & Yamashita, 2015; Pietta & Tononi, 2021; Randelli & Martellozzo, 2019; Sharifi, 2016; Sharifi & Yamagata, 2016; Siebeneck et al., 2015; Termorshuizen et al., 2007; Toseroni et al., 2016; Yale Center for Environmental Law and Policy et al., 2012; Zhu et al., 2018). The aim is to tailor the indicators used, discussed and agreed upon in previous studies to the current cases, searching for at least the most similar proxy available; in addition, further indicators are included to represent unique local characteristics. Overall, such an effort should take into account the replicability of the process, the easiness of collecting information, and the comparability of the analyses. Despite such premises, it is here anticipated that the availability of data significantly affected the overall selection and quantification of indicators.

5.5.1. *Marche region*

The first phase of the methodology uses indicators associated to the *attributes* (Tab. 5.6). For this phase, previous examples of application are less in number; also, this phase is the most flexible, adapting the indicators to the selected risk scenario. Consequently, it is particularly significant to clarify selection process of such indicators. Notably, the availability of relevant data may significantly influence this process. In general terms, these indicators should represent how resilience and sustainability were manifested during extreme events, namely floods here.

Referring to the *resilience core*, the *learn attribute* verifies whether the community learnt from the flood events, reducing their exposure to flood hazard; in this case, the related proxy was the rate of moving away from the flooding areas. The indicator related to the *absorb attribute* concerns the capacity to withstand the flood impact; hence, here it quantifies the grants conceded to cope with the suffered damages, roughly assuming a direct proportion between the amount of grants and of damages (and indirect proportion with the ability to manage flood events). Lastly, the indicator for the *recover attribute* evaluates the extent of the achieved restoration, in this case at least of the economic assets of the community after the flood events.

The *sustainability core* followed a slightly different perspective, focusing on alterations that could hamper the ability of the environment to perform the natural processes. The *functions attribute* investigates the anthropogenic alterations that undermine the ability of natural ecosystems to manage (absorbing and draining) water; hence, the related proxy was the conversion of natural land into urbanised and industrialised areas. The *services attribute* concerns the effects of human activities on the water-processes ongoing in natural environment connected with its flow and availability; in this case, it was represented by the variation in water abstraction for human uses from spring and water courses. Lastly, the *integrity attribute* is related to the state of the environment in terms of species particularly suffering from anthropogenic causes, hence the reference to their conservation status as a measurable proxy.

Tab. 5.6 - Indicators of the cores per each attribute for the Marche region case study

Core	*Attribute*	*Indicator*
Resilience	*Learn*	Variation of population exposed to flood hazard
	Absorb	Grants for extraordinary and emergency interventions
	Recover	Ratio of tax revenue after 2 years and on the year of the last flood event
Sustainability	*Functions*	Variation of land take
	Services	Variation of water intake
	Integrity	Number of species in inadequate or bad conservation status

In the second phase of analysis, indicators are related to the *dimensions* of the *cores* (Tab. 5.7). Here, the aim is to depict the overall characteristics of the *sub-units* to evidence the features that most efficiently differentiate the showed disaster behaviours. In general terms, this phase benefits the most from the previous research endeavours, some of which were introduced in the literature review above. Hence, when possible, multiple indicators were tested for a same *dimension* to identify the most suitable one.

Concerning the *resilience core*, some indicators represent the basic characteristics of a community, along with some factors that have been suggested to influence its resilience, because of either their intrinsic fragilities (presence of elderlies and of women, population density) or their lack of familiarity with the area (presence of non-native people). At the same time, the cohesion of the community was included, both from a private (involvement in local organisations) and a public (support of local organisations) perspective, and for the possibility of inter-connection (internet access). Other indicators try to capture assets, either non-material (level of education) or material (status of employment, income) that should enhance the ability to cope with extreme events. Similarly, public efforts to sustain fragile situations (investments to alleviate poverty and critical conditions) have been often considered, along with their effects on the area (difference between people living and only residing in the area, hence working elsewhere). The relevance of the health and emergency systems emerges particularly evident during an extreme event, hence maintaining their performance to the highest levels is critical (structure of the health system, care of fragile people, quick activation of first respondents). At the same time, a community lives within an engineered space, thus its safety (support of mitigation efforts, year of building construction), efficacy (extension of roadways) and efficiency (wasted water after abduction) shape everyday life, but they might as well enhance a prompt response in case of a disaster.

On the other hand, indicators related to the *sustainability core* suffered most from the complexity of retrieving information. Therefore, unfortunately, it was not possible to collect as much indicators as for the *resilience core*. In this case, the aim is to keep trace of significant alterations of the natural environment (conditions of the environment, presence of quasi-natural areas, presence of environmentally valuable areas) and of the health of ecosystems (support of the production of raw materials and valuable products). At the same time, it appeared relevant to evaluate the permanence of physical features (variation in air quality and in water quantity during extreme events), as well as the evident impacts of human activities (areas converted for agricultural purposes, expansion of livestock, induced fragmentation of natural areas).

Tab. 5.7 - Indicators of the cores per each dimension for the Marche region case study

Core	*Dimension*	*Indicator*
Resilience	*Demographic*	Immigrants
		Population over 65 y.o.
		Population over 80 y.o.
		Female population
		Population density
	Social	Population with higher education
		Area with UWB internet access
		Volunteers in no-profit organisations dealing with social welfare and civil protection
		Public revenues of no-profit organisations dealing with social welfare and civil protection volunteer expenditure of no-profit organisations dealing with social welfare and civil protection
	Economic	Employment
		Unemployment
		Taxable income
		Social expenditure for social welfare
		Present population
		Difference in present and resident population
	Health	Mental health discharges
		Residence facilities for the elderly
		Beds in residence facilities for the elderly
		Welfare facilities (non-residence) for the elderly
		Total welfare facilities for the elderly
		Hospital staff
		Hospital beds
		Average time of arrival on place
		Average time of arrival on place over the past 5 years
	Infrastructural	Local expenditure for mitigation
		Extension of municipal roads
		Extension of non-municipal roads
		Wasted drink water
		Average building construction year

Sustainability	*Ecosystems integrity*	Habitats in inadequate/bad status Grassland and pasture Woods owned by farms Geobotanical value
	Ecosystem benefits	Forests for woods D.O.C. and I.G.P. producers
	Physical processes state	Flood discharge variation PM_{10} average value PM_{10} average difference PM_{10} average value in most populated cell PM_{10} average difference in most populated cell
	External pressures	Agricultural area Heads of livestock Heads of cattle Urban-transport fragmentation pressure

5.5.2. *Hokkaidō*

The rationale that guided the choice of the indicators for the Hokkaidō case study (Tab. 5.8 and Tab. 5.9) closely follows that discussed for the Marche region. Consequently, it might be more interesting to spend some attention on the differences among the indicators and to the implications for the adopted methodology.

Concerning the first phase of the analytical process, the overarching aim was to keep the indicators as similar as possible, in order to optimise the comparability and possibly reveal differences due to local features. Furthermore, the preliminary analyses for the Marche region confirmed the suitability of the selected indicators. Nevertheless, retrieving such data resulted rather complex, in particular for the *learn attribute*. Hence, other indicators were tested as substitutes, though maintaining unaltered the underlying rationale as far as possible. In this case, in addition to evaluating the resettlement propensity, the acquired knowledge and awareness of flood events was considered related to the extension of the area that suffered from the flood intended, representing the exposure of assets to hazardous conditions, and to the distance of the built-up areas from the water body, assumed related to the awareness of local flood dynamics.

The *sustainability core* presents broader differences. Also in this case, data availability played a critical role, preventing the adoption of the same indicators. Consequently, the focus shifted towards maintaining their meaning as close as possible and assuring the performance of the analysis as high as possible. In particular, the variation in land use (selected for the Marche region case study) was evaluated in terms of financial transactions related to lands, and vegetation that was altered throughout the recent years (*functions attribute*). The alteration of local ecosystem services related to water bodies was described by the extension of the assets related to the power supply (*services attribute*). Lastly, the *integrity* of the environment was investigated through the distribution of a particularly problematic species, that is the raccoon (洗熊 or 浣熊, *araiguma*), an alien species that heavily affected the local Japanese raccoon dog (狸, *tanuki*) since its introduction in the late ’80s.

Tab. 5.8 - Indicators of the cores per each attribute for the Hokkaidō case study

Core	Attribute	Indicator
Resilience	*Learn*	Total affected area
		Distance from the nearest water body
		Population exposed to flood hazard
	Absorb	Flood damages
	Recover	Percentual difference in income after 2 years and on the year of the last flood event
Sustainability	*Functions*	Land transaction
		Altered vegetation
	Services	Number of establishments
		Employees in power supply
	Integrity	Distribution of raccoon (浣, *araiguma*)

Differences among indicators remain also in the second phase of the analysis, although in this case they should be encouraged as a means to represent local characteristics.

The *demographic dimension* maintains some homogeneity, as the previous considerations remain valid. On the other hand, the *social dimension* recognises some alternative indicators, mainly due to their availability: for instance, the interconnection within the community is still considered, but through a different proxy (related to television); similarly to the possibility to interact with each other and to the public support to local initiatives (presence and dimension of public facilities). The evaluation of the educational level is comparable, although the Italian and Japanese educational systems are slightly different, for instance concerning the compulsory period, which ends one year earlier for Japan (15 years old) compared to Italy. The assumptions behind the *economic dimension* remain the same, though it is easier to trace the incoming population, while the *health dimension* captures the investment rather than the efficacy of first responders. Lastly, the *infrastructure dimension* shows the only relevant variation, as rather than their efficacy, the focus is on the availability of public services (presence of septic tanks in place of public sewerage system).

Tab. 5.9 - Indicators of the cores per each attribute for the Hokkaidō case study

Core	*Dimension*	*Indicator*
Resilience	*Demographic*	Immigrants
		Population over 65 y.o.
		Population over 75 y.o.
		Population over 80 y.o.
		Female population
		Population density
	Social	Population with compelled education
		Population with university education
		Tv subscriptions
		Satellite subscriptions
		Public halls
		Public halls and similar infrastructures
		Personnel of public halls and similar infrastructures
		Sport facilities
		Personnel of sport facilities
	Economic	Employment
		Taxable income
		Social welfare expenses
		In-migrants from other municipalities
		Inflow of population from the same Prefecture
		Inflow of population from a different Prefecture
		Total inflow of population
	Health	Welfare facilities for the elderly
		Nursing care facilities for the elderly
		Medical facility doctors
		Hospital with medical beds
		Hospital beds
		Beds in general clinics
		Firefighting expenses
	Infrastructural	Disaster recovery expenses
		Extension of roadways
		Population served by septic tank
		Average building construction year
Sustainability	*Ecosystems integrity*	Forest and grassland
		Forests
		Grasslands
		Wildlife sanctuary
	Ecosystem benefits	Private forests
		Fisheries and aquaculture entities
	Physical processes state	Water intake of water supply businesses
		Difference from optimal pH value in river water
	External pressures	Cultivated land area
		Revenue from livestock
		Revenue from beef cattle

Again, the complexity of retrieving data affected the collections of the sustainability indicators. Here, the *integrity* of the ecosystems was depicted through the extension of natural and quasi-natural areas (forests, shrubs, grasslands, pastures), whereas the retrieved *benefits* were related to raw materials (such as wood) as well as wildlife catches and breeding (in this case related to fishery). The abduction of natural water was employed as a proxy for the induced alteration of the *physical processes*, while the primary sector (agriculture and farming, especially cattle) was assumed as a representation of the human *pressure* on the natural environment.

5.5.3. *Methodological issues*

As previously mentioned, the indicators were selected in order to keep their collection as simple and replicable as possible. Consequently, sources of information that could be easy accessed and that provided official data were preferred, such as the Italian National Institute of Statistics (ISTAT) (ISTAT, n.d.-b) or the Japanese Government Statistics (Japanese Government Statistics, n.d.-b). Nevertheless, some indicators required a specific pre-processing, that will be here presented for the sake of transparency. In particular, when Geographic Information System (GIS) tools were needed, the opensource software QGIS 3.4 *Madeira* and the later QGIS 3.10 *A Coruña* (QGIS, n.d.) were used.

5.5.3.1. Marche region

One of the first issues concerned the administrative boundaries. Indeed, during the studied period some municipalities merged, and the related toponymy changed. However, available data not always followed such variations, hence, some adjustments were necessary in some cases.

In order to perform spatial analysis in GIS environment, administrative boundaries were collected from the Italian National Institute of Statistics (ISTAT) for the year 2018 (ISTAT, n.d.-a). The information is available as a shapefile for three administrative levels: region, province and municipality, comprising the overall national territory. Thus, it was necessary to *select* and retrieve the elements related to Marche region.

Where working in the GIS environment, the adopted Coordinate Reference System (CRS) was the WGS84 UTM32N, identified as EPSG: 32632 (ISTAT, n.d.-a), since it is one of the most widely used CRS (QGIS Documentation, n.d.) and it represents a global geographical standard.

First phase

- **Variation of population exposed to flood hazard**

The Italian Institute for Environmental Protection and Research (ISPRA) compiles reports to describe the condition of risk of the Italian territory, including floods (Trigila et al., 2015, 2018). The Italian law recognises three level of hazardousness related to flood, depending on the probability of the event to happen, quantified through the return period (*D.Lgs. 49/2010 "Attuazione Della Direttiva 2007/60/CE Relativa Alla Valutazione e Alla Gestione Dei Rischi Di Alluvioni"*, 2010). However, it was possible to retrieve data only for the intermediate level, that is the medium probability of occurrence for the Marche region. The difference of exposed population was then referred to the 2015 value (Eq. 3):

$$\frac{pop_{2018} - pop_{2015}}{pop_{2015}} = \Delta pop_{2015-2018} \quad (3)$$

where pop_{2015} and pop_{2018} represent the population exposed to flood hazard in 2015 and 2018, respectively. However, sometimes pop_{2015} equals 0, causing mathematical issues. In such cases, both pop_{2015} and pop_{2018} are added 1, so that the difference remains the same, but solving the otherwise issue. It is acknowledged here that this hampers the assessment, because in this way a variation from 0 to *n* is the same as a variation from 1 to *n*. Nonetheless, it is assumed as an acceptable approximation, as only a minority of the total cases (10 *sub-units* out of 229, 4.37%) is affected.

- **Grants for extraordinary and emergency interventions**

The information related to the public contributions for damages from extreme events was collected from the online legislative archive of Marche region, for every event in the considered time span (Regione Marche, n.d.-d). Grants are considered only if referred to municipalities (hence excluding those for the provinces) and at the point of closure of the payment. They include, among the others, the contributions to displaced population, assistance to population and support to local companies. It is acknowledged here that at the last consultation (July 2019) the available data might be incomplete, since the reimbursement procedures might last many years after the event, though it is accepted as an unavoidable issue.

- **Ratio of tax revenue after 2 years and on the year of the last flood event**

Taxable income was assumed as a proxy of the personal economic condition. In order to retrieve the appropriate information, the year of the last flood was identified for each *sub-unit*. At the time of retrieving data (2019), the latest available information on the website of the Ministry of Economy and Finance (Ministero dell'Economia e delle Finanze, n.d.) referred to 2018, that is the fiscal year 2017. Since the last flood considered here happened in 2015, the longest time span that could be assumed was

2 years. Hence, such 2-year difference was adopted for the analysis. As previously mentioned, a minority of the sub-units (2.62%) resulted in not being affected by any flood event. In these cases, it was assumed that the event of November-December 2013 involved such a large portion (79.91%) of the municipalities, that some effects might reasonably have spilled over such municipalities, too. Eventually, the 2-year difference in taxable income was calculated as a percentual difference referring to the initial value.

- **Land take**

The degree of land take depicts the amount of area converted from natural and semi-natural areas to artificial land uses (EEA, 2019b). Data on land take for Italy can be publicly accessed thanks to the Italian Institute for Environmental Protection and Research (ISPRA) (SINAnet - ISPRA, 2019). At the moment of the collection (2019), data was published for the time period 2012-2018. Given the mentioned changes in the administrative boundaries, collected values were distributed on the base of the proportional areas of the former municipalities, disjoined until 2018. Data concerning the extent of land was retrieved for 2012 and 2018, and transformed into variation.

- **Variation of water intake**

Data was collected from Italian National Institute of Statistics (ISTAT) from the available period of 2012-2015. Also in this case, data is affected by the changes occurred in the municipalities, hence some aggregations were necessary before calculating the differential variation.

- **Biodiversity**

The Habitats Directive (*Council Directive 92/43/EEC*, 1992) provides specific guidelines for the European Countries in order to evaluate habitats and species. Such assessment is performed through a series of parameters that allow to identify the status of conservation, which might be "favourable", "unfavourable-inadequate" or "unfavourable-bad" (Eionet - EEA, n.d.). Here, the focus is on species and two categories are considered: "inadequate", that represents species which need a change in the management strategies, but are not critically endangered, and "bad", that represents species near the extinction, at least locally (SINAnet - ISPRA, n.d.-a). The 3rd Italian report (Genovesi et al., 2014) was consulted in order to identify the relevant species for the Italian territory, summarise such information in an Excel table, identify those in an unfavourable condition, and eventually export it in QGIS. The species distribution was retrieved from the Italian national report as a shapefile, accessible from the SINAnet database (SINAnet - ISPRA, n.d.-b). In QGIS, such files were firstly joined, then cut and merged to the municipal boundaries. In this way, the attribute table presented all species in unfavourable conditions for each municipality. After exporting it in Excel, it was possible to calculate the number of species in unfavourable conditions per each municipality. It is acknowledged here that the species whose spatial distribution was 50x50 km^2 were not included in the evaluation, because such a coarse resolution significantly affected the reliability of the representation (for instance, the species *caretta caretta* was associated to municipalities far from the coast, that is unreasonable). Hence, the general resolution of the species distribution adopted here is limited to 10x10 km^2.

Second phase

- **% employment, % unemployment**

The quantification of the status of employment was particularly affected by the changes in administrative boundaries. Consequently, two different sources were used: the Italian National Institute of Statistics (ISTAT) provided most of the information, although the Marche Region Statistical Informative System (SIS, *Sistema Informativo Statistico*) provided the data for the municipalities not included in the former (Sistema Informativo Statistico - Regione Marche, n.d.-c). The available information was referred to 2011, that is the year of the last census.

- **Hospital staff/pop**

It was not possible to directly retrieve the number of hospital staff associated to each municipality, as the organisation of the local Health System is based on *Aree Vaste*, that are entities broadly corresponding to provinces. Hence here, data was elaborated for each of the 5 *Aree Vaste* and then associated as it is to the municipalities. This follows the assumption that the population of each municipality might rely on all the hospital staff available for the pertaining *Area Vasta*. This metric was calculated from indirect information that can be found on the website of the Regional Health Agency (ASUR), as bonuses distributed among the personnel (Azienda sanitaria unica regionale, n.d.). Documents are available per each *Area Vasta*: excluding directors (assumed not to perform operative roles), the hospital staff can be retrieved for the pertaining *Area Vasta* as reported on the Regional SIS website (Sistema Informativo Statistico - Regione Marche, n.d.-b).

- **Hospital beds/pop**

At the time of collecting information (July 2019), a regional deliberation had recently been approved to redistribute the number of hospital beds among the *Aree Vaste* (*D.G.R. 639/2018 Ridefinizione Della Dotazione*

Dei Posti Letto Della Rete Ospedaliera Marchigiana, 2018). Hence, likewise the previous indicator, data is necessarily referred to that scale. The value is referred to 1000 inhabitants of the pertaining *Area Vasta* to make it comparable among such entities. In this case, data on population was retrieved from the Marche Region Statistical Informative System (Sistema Informativo Statistico - Regione Marche, n.d.-a).

- **Average time of arrival on place, average time of arrival on place over the past 5 years**

Information was retrieved from the latest available version (at the time of data collection, July 2019) of the Firefighters Statistical Yearbook (Signoretti & Vertola, 2018). It should be noted that in this case the province of Fermo is under the jurisdiction of the provincial command of Ascoli Piceno, consequently it was not possible to disaggregate the information for the two provinces.

- **Local expenditure per capita for mitigation**

Information can be retrieved from the online legislative archive of the Marche Region (Regione Marche, n.d.-d), through a search with the keyword "*rischio idr*", then selecting only the documents referred to "*rischio idraulico*" (flood risk, in Italian), hence distinguishing from landslide risk ("*rischio idrogeologico*", in Italian). Afterwards, a validation was performed, in order to check for their consistency. In this case, it was verified either through the state of payment settlement or by consulting the website of the Marche region devoted to local defence interventions (Paesaggio Territorio Urbanistica Genio Civile - Regione Marche, n.d.). In addition, the latter source was also accessed to record further projects. Similarly, it was deemed relevant to consult the website of ReNDiS ("*Repertorio Nazionale degli interventi per la Difesa del Suolo*"), a project promoted by the Italian Institute for Environmental Protection and Research (ISPRA) on the behalf of the Ministry of the Environment, Land and Sea to monitor the progress of local actions against flood and landslide risks (ReNDiS - ISPRA, n.d.-c). Data was extrapolated from the list of interventions, selecting "flood", "coastal" and "mixed" among the typologies (ReNDiS - ISPRA, n.d.-b) and imposing "Marche Region" as a limiting criterion to visualise and thus access the available documents related to regional decrees (ReNDiS - ISPRA, n.d.-a). Likewise, information was crosschecked referring to the OpenCUP database (OpenCUP - DIPE, n.d.), that is a website that allows to verify the state of a project financed through public funds via its CUP ("*Codice Unico per conoscere gli investimenti pubblici*") identifier. This initiative is promoted by the Department for the Programming and Coordination of Economic Policy (DIPE), part of the Prime Minister's Office. Lastly, some specific legislative documents were considered: D.G.R. 1554/2017 and "*Terzo Atto Integrativo all'Accordo di Programma Finalizzato alla Programmazione e al Finanziamento di Interventi Urgenti e Prioritari per la Mitigazione del Rischio Idrogeologico*" (*Terzo Atto Integrativo all'Accordo di Programma*, n.d.).

Even though the primary objective was to identify the specific public investment per each municipality, it was not always possible to deduce it from the available documents, as the values might be referred to a set of municipalities. In such cases, the adopted criterion consists of the proportion of coastline or of waterways among the concerned municipalities. In order to estimate such proportions, the shape files were retrieved from official databases: the Italian National Institute of Statistics (ISTAT) for the coastline (ISTAT, n.d.-c), and the Italian Institute for Environmental Protection and Research (ISPRA) through the service SINAnet ("*Rete del Sistema Informativo Nazionale Ambientale*") for waterways (SINAnet - ISPRA, n.d.-c). With regards to waterways, among the available typologies, only courses identified as "*fiume*" (river, in Italian) were selected and *cut* within the borders of the pertaining municipality; then their length was calculated through the specific function (*$length*) in the Field calculator instrument, available in QGIS 3.4. Proportions, both of coastlines and waterways, were all calculated in Excel.

- **Municipal road km/pop, non-municipal road km/pop**

Data was retrieved per each municipality from the website of the Ministry of the Interior (Dipartimento per gli Affari Interni e Territoriali - Ministero Dell'Interno, n.d.). The information was available in the section "*Certificati Consuntivi*", selecting the sheets responding to the D.P.R. 194/1996. Unfortunately, this limits the availability of data, as the latest source dates to 2015. Roadways were considered only when under the jurisdiction of the municipalities, and their quantification was specified in terms of roads both within and outside urbanised areas. Such values were then summed and related to the municipal population.

- **%wasted drinking water**

Information was retrieved from the Italian National Institute of Statistics (ISTAT), for the year 2015. Measures were available for both input and distributed water, hence the percentual difference related to the input value was used.

- **Average building construction year**

Data collected from the Italian National Institute of Statistics (ISTAT) informed on the status of the residential real estates. The date of construction derived for the 2011 census; data concerned the number of residential buildings per 9 time periods, spanning from "1918 and before" to "2006 and after”. The indicator was calculated as a weighted mean in order to identify the average date of construction of buildings as one of the above 9 time periods. In the case of merged municipalities, the assets of the former municipalities were first associated to the merged municipality and then the overall mean was calculated. It is important to note that the result consisted of a categorical variable, rather than a continuous variable as ideally requested for a discriminant analysis. Unfortunately, this was the only available approximation to estimate the age of the local estates.

- **#habitats in inadequate/bad status**

In this case the status of conservation of the habitats was considered, again in relation to the Habitat Directive (*Council Directive 92/43/EEC*, 1992). Information is disclosed by the European Environment Agency in an open access format (EEA, 2015a; EU Open Data Portal, 2019). The classification envisions a specific symbology that derives from the official reporting guidelines (EEA, 2015b), that includes a code for the status and a qualifier for the expected future trends. In this case, the considered status of conservation was “unfavourable” and “unknown” for any kind of qualifier, in order to include all possible negative conditions (see Tab. 5.10). The underlying assumption is that not only an unfavourable condition is undesirable, but also a lack of knowledge, because it does not allow to adequately manage that habitat.

Tab. 5.10 - Symbology adopted when reporting under the Habitat Directive (92/43/EEC), including all the possible conservation status and trends

	Symbol	*Meaning*
Conservation status	Fv	Favourable
	U1	Unfavourable-Inadequate
	U2	Unfavourable-Bad
	XX	Unknown
Qualifier	+	Improving
	=	Stable
	-	Declining

Lastly, observing that the status of conservation varies also depending on the geographical scale, the minimum available geographical scale is here preferred, being the national scale. Once data was visualised in QGIS, the number of habitats for the unfavourable and unknown status were counted per each municipality.

- **geobotanical value**

As a complementary information to the previous indicator, it was deemed interesting to include the areas that experienced a limited impact from human activities. To this end, the REM (*Rete Ecologica Marche*) initiative, founded by the Marche Region, availed (Regione Marche, n.d.-g). Part of its activities is the evaluation of the "*valenza geobotanica*" (geobotanical value), that represents the environmental quality and vulnerability of a certain area, thus informing conservation actions (Regione Marche, n.d.-f). In particular, it is possible to retrieve the map of geobotanical value (Regione Marche, n.d.-g) in pdf format, that was interpreted as a *raster* in QGIS, *georeferred* and used as a base *layer* for the municipal boundaries. The highest and lowest class of geobotanical value were identified and reported per each municipality. It is acknowledged here that this is another categorical data, once more accepted as a limitation.

- **Flood discharge variation**

The European Environment Agency (EEA) quantified and distributed the trends in flood discharge over a period of 50 years (EEA, 2019d). In particular, it is possible to use a shapefile with several points of measure distributed all over the European territory. Working in a GIS environment, after cutting the point layer with that of the municipal boundaries and then merging them, the resulting *layer* held all the relevant characteristics for this assessment, since the attribute table returned the trends of flood discharge per each municipality. At this point, the values were exported in percentual variation of the mean annual flood discharge per decade (EEA, 2019d) in an Excel sheet, in order to average the eventual multiple measures associated to a municipality.

- **PM_{10} average, PM_{10} difference average, PM_{10} average for largest exposed population, PM_{10} difference average for largest exposed population**

Information on the distribution and concentration of PM_{10} is available for whole European area (EEA, 2013). Data is provided interpolated over a 1 km- or 2 km-grid, though the former was adopted in the present case in order to maximise the resolution. Data was retrieved for the year 2017, the latest available. It was possible to cut and merge such grid with the municipal boundaries, so that the attribute table included all the relevant information. The PM_{10} annual average values and the interannual difference in PM_{10} annual average were selected, both for the highest absolute values and the values corresponding to the grid cell with the largest human exposure (in terms of population).

- **Urban-transport fragmentation pressure**

Data was retrieved for Europe in terms of fragmentation pressure caused by urban and transport infrastructure expansion (EEA, 2019a, 2019c). Values are presented as "seff value", that is the number of fragmented meshes per 1 000 km^2, in other words a measure of density of fragmentation (EEA, 2019c). Such values might span from 0 to infinite:

the higher the value, the higher the landscape fragmentation (EEA, 2019c). Values are categorised within classes associated with a different degree of fragmentation pressure (Tab. 5.11).

Tab. 5.11 - Correspondence of "seff values" and fragmentation classes

Seff values (number of meshes per 1 000 km^2)	*Fragmentation class*	*Fragmentation class value*
0-1.5	Very low	1
1.5-10	Low	2
10-50	Medium	3
50-250	High	4
> 250	Very high	5

Source: adapted from (EEA, 2019c, 2019a)

The available data consists of a shapefile reporting the fragmentation class values for Europe. Therefore, it was possible to use this *layer* as a base for the municipal boundaries in QGIS, thence identifying and exporting on a separate table the highest value per each municipality. It is here acknowledged that, even though the original "seff values" correspond to a continuous variable, the available information is limited to a class, hence a categorical variable.

5.5.3.2. Hokkaidō

Following from the previous discussion, in this case, the Coordinate Reference System (CRS) was set as WGS84 UTM54N, that is EPSG:32654, the most suitable to represent Japan (epsg.io, n.d.).

The Geospatial Information Authority of Japan (GSI) provides a series of geospatial products, including administrative, demographic and infrastructural information, lastly revised in 2016, hence consistent with the municipal mergers occurred in 2015 (GSI, n.d.). In particular, it is possible to access data on the area defined by political boundaries, identified as "polbnda" among the available *shapefiles* (ISCGM, 2012). This is especially convenient, since the information comprises the *fields* of "*State/Province/Prefectural name*" ("*nam*"), "*local administrative area name*" ("*laa*") and "*administrative code*" ("*adm_code*") (ISCGM, 2012, p. 22). Consequently, since the *shapefile* covers the whole Japanese territory, it was sufficient to *select* only the elements pertaining to "*Hokkai Do*" in order to obtain the geospatial representation of the municipalities of this prefecture.

A further basic information concerning the local population was retrieved from the most recent survey that comprehensively involved the municipalities, performed in 2015 (Japanese Government Statistics, n.d.-c).

First phase

- **Distance from the nearest water body**

Data was retrieved from the Geospatial Information Authority of Japan (GSI, n.d.). The basic *layers* employed represented the municipal boundaries, the build-up areas and the water bodies, these latter encompassing rivers, dams or any other inland water body (ISCGM, 2012). At this point, it was possible to estimate the distance of each urbanised area from the nearest water body employing *Measure Line*, a *tool* included in QGIS. During the process, any kind of water body was admitted, except for those seemingly representing springs, since it appeared unreasonable that they could trigger a serious flood. Then, data was reported and associated to each municipality.

- **%population exposed to flood hazard**

Data collection required information on the distribution of the population and on the extension of the flooding areas. The Japanese Government Statistics provided a 500m-grid representation of the the population for the Hokkaidō area, in the world geodetic latitude/longitude form (Japanese Government Statistics, 2010). Several *shapefiles* were *merged* in order to obtain a single mesh grid for the overall prefecture. The Ministry of Land, Infrastructure, Transport and Tourism provides access to the maps elaborated after the 2015 Flood Prevention Act (MLIT, n.d.-b). Notably, such maps do not encompass the whole Hokkaidō area, rather they are shaped for the 13 major river systems, including a total of 60 rivers (MLIT, n.d.-b). For each river system, several alternatives are available, the most relevant being: "assumed maximum scale", "plan scale", "inundation duration" and other representation related to physical properties or induced damages of floods. In the present case, maps designed for the "plan scale" ("計画規模" in Japanese) were selected in order to adhere to development planning approach. Maps were retrieved in pdf format, and preliminary *georeferred* to be used in QGIS. *Ground Control Points* (GCP) were engaged to the features of rivers and municipal boundaries, even though when maps presented overlaps, the correspondence among such rasters was preferred in order to enhance a consistent representation of the local areas and to overcome the simplifications of the other vector features. An average of around 80 GCPs appeared to be generally sufficient to deliver an acceptable *georeferred* outcome. The adopted algorithms varied in order to optimise the transformation, although the *Polynomial 1* type and *nearest neighbour* or *linear* resampling method was often preferred. Then, the rasters served as basis to draw the shapefiles: these *vector layers* included the *polygons* representing all the flood inundation areas. Eventually, all the shapefiles referring to different rivers (but same river system) were progressively merged. At this point it was possible to overlay the municipalities with the population distribution and the flood inundation areas. Per each municipality, the layer of the flood inundation area was cut within the municipal borders and then used to cut the layer of the population distribution. Consequently, it was possible to obtain the inhabited mesh cells included in a flooding area: the attribute table was then exported in Excel to calculate the total amount of exposed population per each municipality. It is noteworthy that in this way some municipalities resulted with no reported inhabitants residing in flooding areas. Although this might correspond to real flood risk conditions, it is here acknowledged that it might also be due to the limited extension of the inundation maps. Nonetheless, it was assumed as an acceptable limitation, being consistent throughout Hokkaidō.

- **Land transaction**

Data related to land transactions was accessed on the website of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, n.d.-i). The disclosed information employed here refers to the areal extension of land transactions, retrieved for year 2015 and 2016 (MLIT, n.d.-a). Every document includes the selected year and the two previous years, hence it was possible to aggregate data and calculate the ratio between the areal extension of land transactions for 2016 and 2014.

- **Altered vegetation**

Information on the altered distribution of vegetation is provided by the Biodiversity Center of Japan, in terms of "Vegetation survey (vegetation naturalness survey)" ("植生調査(植生自然度調査)", in Japanese) (Biodiversity Center of Japan, n.d.-b). This investigation continued through the years: the last available reports refer to 1999 onwards (6th and 7th survey), though the latest data on the altered vegetation was included in the previous 5th survey, referred to the period 1994-1998 (Biodiversity Center of Japan, n.d.-a, n.d.-b). Here, the *shapefiles* referred to the areal representation of altered vegetation were used, that are codified with the root "*vg5*" followed by a progressive number for the different prefectures and local branches (Hokkaidō has seven branches, that are n°51 to 57), and the label "a" to differentiate from the linear representation. All the *layers* were *merged* to cover the prefectural area and the areal extension estimated through the *Field calculator* (function: *$area*). Lastly, this *layer* was merged with the municipality boundary *layer*. It was then possible to extract the information and proceed to aggregate the area extensions per each municipality. This revealed that that not all areas (represented as *polygons*) had been associated to a municipality: in these cases, the polygons were identified in the GIS environment and manually associated. Eventually, the areal extension of the altered vegetation could be related to the overall extension of each municipality.

- **Distribution of raccoon**

The Biodiversity Center of Japan provides also the results of the "Survey of habitat distribution for birds and beasts (bears, etc.)" ("要注意鳥獣(クマ等)生息分布調査", in Japanese), where the distribution of the *araiguma* raccoon can be retrieved (Biodiversity Center of Japan, n.d.-c). Data is provided as a shapefile, as a mesh with a resolution of 5x5 km^2. After limiting the representation to Hokkaidō, the information displayed in the field "*H29*" of the attribute table was employed, since it represents the "Inhabited mesh in "2017 bird and beast (bears, etc.) habitat distribution survey operations"" ("「平成29年度要注意鳥獣（クマ等）生息分布調査業務」において生息ありのメッシュ"", in Japanese). Hence, it was possible to identify the meshes representing the presence of the *araiguma* raccoon and later merge them with the layer of the municipalities. Then, the Field calculator allowed to estimate the area extension of the meshes (function: *$area*). Exported the information and aggregated the meshes per each municipality, it was possible to obtain the number of meshes and thus the total extension of the area concerned by the diffusion of the *araiguma* raccoon, as well as the proportion of the affected area.

Second phase

- **Roadways m/pop**

Information was retrieved from the Geospatial Information Authority of Japan (GSI) website (GSI, n.d.), as a line shapefile for all Japanese roads. After selecting the elements pertaining to Hokkaidō in a separate shapefile, it was possible to associated it with the *layer* of the municipalities. Then, an analysis tool of QGIS was employed, that automatically aggregates and calculates the lines contained within polygons ("*Sum Lines Lengths*"). The outcome consists in the extension and the number of segments per each polygon, in form of additional attributes to the polygon shapefile. Eventually, the required information could be extracted and referred to the local population.

- **Wildlife sanctuary**

In Japan, a means for protecting wildlife species was the establishment of Wildlife Special Protection Areas, where any anthropic activity require a specific permission (Ministry of the Environment, n.d.-b). In this case, data was retrieved from the National Land Numerical Information, provided by the Ministry of Land, Infrastructure, Transport and Tourism as a shapefile for each prefecture and two survey years, 2009 and 2015 (MLIT, n.d.-h). In the GIS environment, the layer for Hokkaidō wildlife sanctuaries was first simplified by dissolving all the geometries into one polygon, and later merged to the layer of the municipal boundaries. The Field calculator (function: *$area*) allowed to estimate the area extent of each polygon, pertaining to a specific municipality, after some manual, necessary adjustments. Eventually, values were referred to the municipal area extension.

- **Water intake**

Information was retrieved from the Hokkaidō Prefectural Government website, for the year 2015 (Environment and Life Department - Hokkaidō Prefectural Government, 2017). In particular, the sections II-2 (水道事業の概要, "Outline of water supply business", in English) and II-7 (簡易水道事業の取水状況, "Water intake status of simple water supply business", in English) were used. The used measures are under the label "Actual annual water intake (thousand m^3)" ("実績年間取水量 (m^3)", in Japanese) for section II-2, and "total (m^3)" ("合計 (m^3)", in Japanese) for section II-7. This double reference was necessary because depending on the dimension of the served community, the supply of clean water might refer to two different institutions, though it might also happen that the same municipality benefits from both services. In addition, in section II-2 some municipalities were aggregated under one water supply business, hence the allocation of supplied water was based on the proportion of the served population. On the contrary, in section II-7 several local services crossed the same municipality, hence an aggregation was necessary, though this process was performed also for Kitami in section II-2. Values were then summed for all the municipalities (values from section II-2 were first converted in m^3) and referred to the local population. It is acknowledged here that, given the data processing from section II-2, this value might lose some relevance for municipalities that were originally aggregated. Nevertheless, this limitation was accepted here because it still provided an estimation of the magnitude of water demand.

- **Water quality**

The Hokkaidō Prefectural Government discloses information on water quality through a database and a webGIS, that are free to access

(Hokkaidō Prefectural Government, n.d.). Data is available from 1971 to 2018 and in sampling points all over the prefecture. In this case, the year 2015 was selected. A preliminary operation associated the sampling points to the respective municipality, by geolocalising each point by means of different sources, for instance Google Maps webservice (Google Maps, n.d.), maps developed by local authorities (Ochiishi Marine Vision Council, n.d.), official documents (Tokachi River Basin Committee, 2008) and plans (Hokkaidō Development Bureau, 2018). Afterwards, per each sampling point, the pH value with the larger deviation from a common reference was identified and reported on a separated list. Such reference value was set as $pH = 7.5$, after comparing the indications of different authorities, in terms of optimal ranges and values for this parameter depending on scope and water source (Enderlein et al., 1997; European Economic Community, 1978; *Council Directive 75/440/EEC* Concerning the Quality of Surface Water Intended for the Abstraction of Drinking Water in Member States, n.d.; Ministry of the Environment, n.d.-a; United States Environmental Protection Agency (USEPA), 1986; Wakayama, 2010).

6. *Results*

The results of the application of the proposed methodology will be described in the following paragraphs, separately per each one case study. As mentioned, in some cases several combinations of indicators were tested to identify the most reliable one (Tab. 6.1). In general terms, the selection criteria were the stability of the process iterations and the strength of the indicators. Nevertheless, here only the most performing combinations are discussed.

Tab. 6.1 - Number of tested combinations of indicators per each phase of analysis of each core, per each case study

Case study	*Phase of analysis*	*Core*	*Number of tested combinations*
Marche region	first (cluster analysis)	resilience	1
		sustainability	2
	second (discriminant analysis)	resilience	12
		sustainability	12
Hokkaidō	first (cluster analysis)	resilience	3
		sustainability	3
	second (discriminant analysis)	resilience	15
		sustainability	10

6.1. Marche region

6.1.1. *First phase – classification*

As previously mentioned, the proposed methodology encompasses two main phases. The first phase aims at identifying the level of resilience and of sustainability per each *sub-unit*, in this case per each municipality, through a cluster analysis. Three indicators per each *core* were selected, each representing a different *attribute*. First, a cluster analysis using the Ward's method was performed. Here, the STATGRAPHICS Centurion 18 (v. 18.1.12) software allowed to use standardised indicators (z-values), select Euclidean distance and request three final clusters. The desired outcome consisted in the centroids of the clusters, saved in a separate file. Secondly, the cluster analysis used the k-means method. Here, the SPSS Statistics (v. 19) software allowed to select once more the z-values and request three clusters, while opting for "*iterate and classify*" technique and using as input of the initial centroids those obtained through the previous step. The procedure in SPSS performs also a set of statistical tests, among which the ANOVA table was selected. At the end of the procedure, the belonging to a specific cluster was saved per each municipality. In the following lines the results for each *core* will be described.

6.1.1.1. Resilience

The *resilience core* was described through indicators related to the social exposure to flood hazard, the entity of flood damages and the economic effects of the last flood (Tab. 6.2).

Tab. 6.2 - Indicators and their codes per each attribute of the resilience core

Core	*Attribute*	Indicator	Code
Resilience	Learn	Variation of population exposed to flood hazard	POP_FLOOD
	Absorb	Grants for extraordinary and emergency interventions	EMERG_GRANT
	Recover	Ratio of tax revenue after 2 years and on the year of the last flood event	IRPEF_VAR

The cluster analysis following the Ward's method resulted in the centroids per each of the requested clusters (Tab. 6.3).

Tab. 6.3 - Initial centroids per each cluster and each indicator of resilience

Indicator	*Cluster*		
	1	2	3
POP_FLOOD	-0.11582	-0.22801	1.54249
EMERG_GRANT	-0.22176	-0.20902	2.15162
IRPEF_VAR	0.54852	-0.78761	-0.72468

The centres of the clusters appear to be rather differentiated, each centroid belonging to a different quarter of the ideal space defined by the three indicators, although the values are not particularly dissimilar in absolute terms for the first two clusters.

The following analysis following the k-means method refined these centroids. The process required three iterations to stabilise over the final centroids, that remained well differentiated (Tab. 6.4 and Tab. 6.5).

Tab. 6.4 - Variation in the position of the centroids per each iteration

Iteration	*Changes in the centroids*		
	1	2	3
1	0.116	0.204	0.555
2	0.031	0.043	0.000
3	0.000	0.000	0.000

Tab. 6.5 - Final centroids per each cluster and each indicator of resilience

Indicator	*Cluster*		
	1	2	3
POP_FLOOD	-0.15104	-0.14285	1.96669
EMERG_GRANT	-0.32130	0.01562	2.46632
IRPEF_VAR	0.64446	-0.78535	-0.89411

The trend of the final centroids could be represented in a bar chart, in order to visualise and differentiate each cluster (Fig. 6.1).

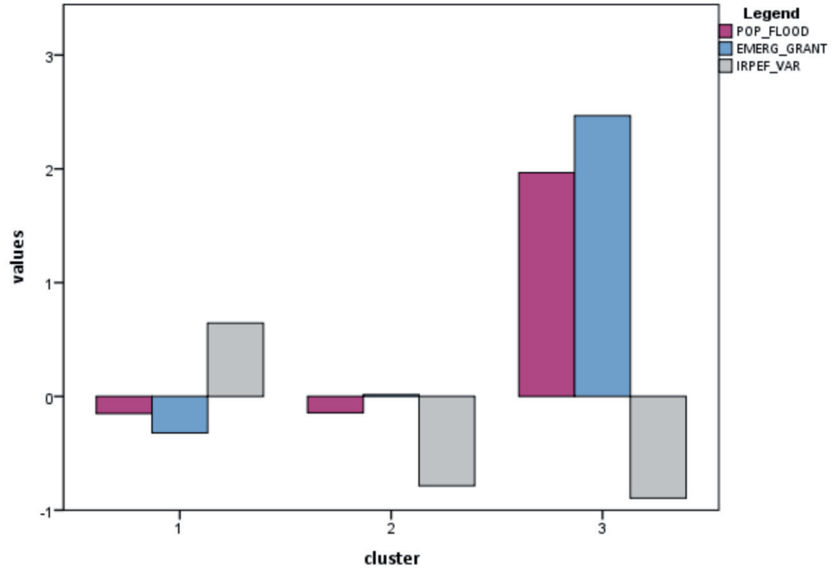


Fig. 6.1 - Bar graph of the final centroids per each cluster and each indicator of resilience

The ANOVA table (Tab. 6.6) allowed to assess the effectiveness of the performed analysis verifying that all the indicators were statistically significant (Sig. < 0.001, per each indicator) in determining the differentiation in clusters of the municipalities. In addition, IRPEF_VAR and EMERG_GRANT appeared to hold the highest and most comparable weights (F = 122.460 and F = 106.185, respectively).

Tab. 6.6 - ANOVA table

Indicator	*Cluster*		*Error*		*F*	*Sig.*
	Mean Square	*df*	*Mean Square*	*df*		
POP_FLOOD	33.269	2	0.714	226	46.567	0.000
EMERG_GRANT	55.228	2	0.520	226	106.185	0.000
IRPEF_VAR	59.290	2	0.484	226	122.460	0.000

Eventually, the collected information allowed to sort the municipalities, although the clusters were unevenly populated: the largest portion of the municipalities belongs to cluster 1 (127), followed by cluster 2 (87) and 3 (16) (Tab. 6.7).

Tab. 6.7 - Number of cases (municipalities) per each cluster of resilience

	1	127
Cluster	2	86
	3	16
Cases	Valid	229
	Missing	0

6.1.1.2. Sustainability

The *sustainability core* was investigated through a similar procedure. The selected indicators concerned the rate of land take, the variation of water intake and the conditions of local species (Tab. 6.8).

Tab. 6.8 - Indicators and their codes per each attribute of the sustainability core

Core	*Attribute*	*Indicator*	*Code*
Sustainability	Functions	Variation of land take compared to total areal extension	LAND_TAKE
	Services	Percentual variation of water intake	CLEAN_WATER
	Integrity	Number of species in inadequate or bad conservation status	SPECIES_INADBAD

First the initial centroids were derived through the Ward's method and the different position in the space emerged (Tab. 6.9).

Tab. 6.9 - Initial centroids per each cluster and each indicator of sustainability

Indicator	Cluster		
	1	2	3
LAND_TAKE	-0.22040	-0.52605	2.15834
CLEAN_WATER	-0.14408	0.71540	-0.35451
SPECIES_INADBAD	-0.40258	1.48746	-0.13816

The k-means procedure followed. Here, the centroids stabilised in few iterations and their positions were not much altered (Tab. 6.10 and Tab. 6.11). The related bar graph shows their different values (Fig. 6.2).

Tab. 6.10 - Variation in the position of the centroids per each iteration

Iteration	Changes in the centroids		
	1	2	3
1	0.069	0.112	0.142
2	0.010	0.033	0.000
3	0.000	0.000	0.000

Tab. 6.11 - Final centroids per each cluster and each indicator of sustainability

Indicator	Cluster		
	1	2	3
LAND_TAKE	-0.26430	-0.44121	2.11559
CLEAN_WATER	-0.20706	0.80621	-0.24915
SPECIES_INADBAD	-0.40778	1.42621	-0.22329

Eventually, the ANOVA table provided the information on the relevance of the outputs. The high significance is common among all the indicators (all Sig. < 0.001), while the weights evidently differ (Tab. 6.12). The variation of land take appears to hold the highest power (216.286), followed by species in dangerous conditions (135.584) and water intake (23.691).

The process led to an inhomogeneous distribution of the municipalities throughout the clusters, the first one being the most populated (152) of the three (Tab. 6.13).

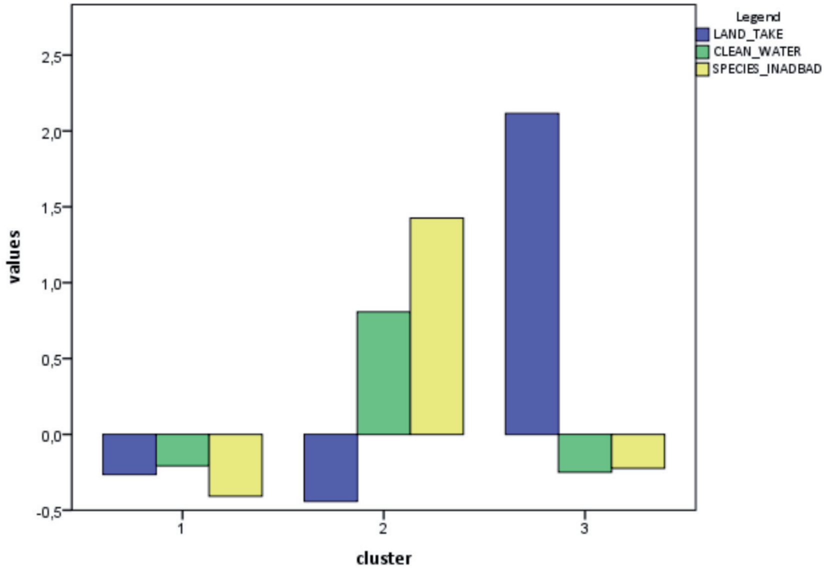


Fig. 6.2 - Bar graph of the final centroids per each cluster and each indicator of sustainability

Tab. 6.12 - ANOVA table

Indicator	*Cluster*		*Error*		*F*	*Sig.*
	Mean Square	*df*	*Mean Square*	*df*		
LAND_TAKE	74.879	2	0.346	226	216.286	0.000
CLEAN_WATER	19.758	2	0.834	226	23.691	0.000
SPECIES_INADBAD	62.178	2	0.459	226	135.584	0.000

Tab. 6.13 - Number of cases (municipalities) per each cluster of sustainability

Cluster	1	152
	2	48
	3	29
Cases	Valid	229
	Missing	0

6.1.2. *Second phase – characterisation*

The second phase of the proposed methodology involves a discriminant analysis. The dependent categorical variables were provided by the previous cluster analysis, while further selected indicators relating to the *dimensions* of the *resilience* and *sustainability cores* worked as independent continuous variables. Among these, the process aims also at identifying the variables that play the most significant role in differentiating among the clusters. The SPSS Statistics (v. 19) software was employed also in this case.

6.1.2.1. Resilience

The selected indicators covered the demographic, social, economic, health and infrastructural facets of a community (Tab. 6.14).

Tab. 6.14 - Indicators and their codes per each dimension of the resilience core

Dimension	*Indicator*	*Code*
Demographic	immigrants	IMMIGR
	population over 65 y.o.	POP_over65
	female population	POP_FEM
	pop density	DENSPOP
Social	population with higher education	HIGH_EDU
	percentage of area covered by UWB internet access	UWB_ACCESS
	volunteers in no-profit organisations	VOLUNT
	public revenues of NPOs dealing with social welfare and civil protection	PUBL_REV_CPASS
	expenditure of NPOs dealing with social welfare and civil protection	EXP_CPASS
Economic	percentage of employment	EMPL_PERC
	taxable income	TAX_INCOME
	social expenditure for social welfare	SOC_EXP
	percentual difference in present and resident population	PRESRES_POP
Health	percentual mental health discharges	MENT_DISCH
	total welfare facilities for the elderly	ELDWELF_FAC
	hospital staff	HOSP_STAFF
	hospital beds	HOSP_BED
	average time of arrival on place over the past 5 years	ARR_TIME
Infrastructural	local expenditure per capita for mitigation	MITIG_EXP
	extension of municipal roads	MUN_ROAD
	percentage of wasted drink water	WAST_WAT
	average building construction year	BUILD_AGE

The SPSS procedure includes some statistical tests, in particular those related to eigenvalues and Wilks' lambda (Tab. 6.15 and Tab. 6.16).

Tab. 6.15 - Eigenvalue statistics of indicators for resilience

Function	*Eigenvalue*	*Percentage of variance*	*Cumulative percentage*	*Canonical correlation*
1	0.281	73.5	73.5	0.469
2	0.102	26.5	100.0	0.304

Tab. 6.16 – Wilks' lambda statistics of indicators for resilience

Test of function(s)	*Wilks' lambda*	*Chi-square*	*df*	*Sig.*
1 through 2	0.708	73.266	44	0.004
2	0.908	20.569	21	0.486

The discriminant analysis provides a number of discriminant functions equal to the number of initial groups minus one. Hence, in this case, the procedure provided two discriminant functions, as the preliminary groups were three. The eigenvalues for both functions are not particularly high, although the difference is sensible anyway. The first function is able to explain the 73.5% of the variation, hence it holds a more significant relevance compared to the other function. Indeed, the canonical correlation is similarly higher (0.469 compared to 0.304), suggesting a robust discriminant power of the functions. In particular, the squared canonical correlation might offer an estimation of the discriminant power of the function: in this case, $0.469^2 = 0.21996$, hence function 1 is able to explain around 22% of the variations among the clusters. It might be interesting to note that the statistical significance of function 1 is rather high (0.004), whereas function 2 is statistically not significant ($0.486 > 0.05$).

Lastly, the equation for the standardised function 1 is (Eq. 4):

$$F = 0.628 * \mathrm{IMMIGR} - 6.320 * \mathbf{POP\_over65} + 7.463 * \mathbf{POP\_FEM} - 0.115 * \mathrm{DENSPOP} - 0.453 * \mathrm{HIGH\_EDU} - 0.262 * \mathrm{UWB\_ACCESS} - 1.306 * \mathbf{VOLUNT} + 0.451 * \mathrm{PUB\_REV\_PCASS} - 0.301 * \mathrm{EXP\_CPASS} + 0.287 * \mathrm{EMPL\_PER} + 0.680 * \mathrm{TAX\_INCOME} + 0.075 * \mathrm{SOC\_EXP} + 0.280 * \mathrm{PRERES\_POP} - 0.617 * \mathrm{MENT\_DISCH} + 0.252 * \mathrm{ELDWELF\_FAC} - 0.718 * \mathrm{HOSP\_STAFF} + 0.952 * \mathrm{HOSP\_BED} - 0.061 * ARR\_TIME - 0.293 * \mathrm{MITIG\_EXP} - 0.336 * \mathrm{MUN\_ROAD} + 0.058 * WAST\_WAT - 0.004 * BUILD\_AGE \quad (4)$$

In Eq. 4 the indicators holding the largest weight are evidenced in bold. Within the combination of indicators of function 1, women, elderly and volunteers in no-profit organisations appear to hold the highest discriminant power (weights: 7.463, 6.320, 1.306 respectively), whereas the average building age, the amount of wasted water and the average arrival time of first respondents, in italics, appear not to play a particular influence on the process (weights: 0.004, 0.058 and 0.061, respectively).

At this point it might be interesting to evaluate the effectiveness of the discriminant function, in particular comparing the clusters assigned to the municipalities at the end of the previous analysis and the clusters that can be predicted as a final step of the discriminant analysis. It is possible to observe that 150 out of 226 municipalities (66%) were associated the same cluster by the two analytical processes. That is, the discriminant function was able to provide an outcome that almost resembles that of the cluster analysis. In might be noteworthy that the function could not associate a cluster to some of the municipalities (3 are missing) because one of the indicators (number of volunteers) was not quantified, hence the analysis could not be performed.

6.1.2.2. Sustainability

An analogous process was developed for the *sustainability core*, starting with the selection of the appropriate indicators (Tab. 6.17).

Tab. 6.17 - Indicators and their codes per each dimension of the sustainability

Dimension	*Indicator*	*Code*
Ecosystems integrity	Habitats in inadequate/bad status	HABITAT_INADEG
	Grassland and pasture	GRASS_PAST
	Woods owned by farms	WOOD_FARM
	High geobotanical value	GEOBOTVAL_HIGH
	Low geobotanical value	GEOBOTVAL_LOW
Ecosystem benefits	Forests for woods	FOR_WOODS
	D.O.C. and I.G.P. producers	QUAL_PROD
Physical processes state	Flood discharge variation	TREND_FLOOD
	PM_{10} average value	PM10_AVG
External pressures	Agricultural area	AGR_AREA
	Heads of livestock	LIVESTOCK
	Urban-transport fragmentation pressure	FRAGM_PRESS

It is noteworthy that this combination includes two metrics concerning the geobotanical value of the local landscape, though the requirement of independence of the discriminant variables is granted. At the same time, including both the most positive and the most negative estimations in a representation of the local sustainability might draw a more comprehensive picture of the local features and issues.

The discriminant analysis provided two discriminant functions and the related statistical tests (Tab. 6.18 and Tab. 6.19).

Tab. 6.18 - Eigenvalue statistics of indicators for sustainability

Function	*Eigenvalue*	*Percentage of variance*	*Cumulative percentage*	*Canonical correlation*
1	1.143	84.1	84.1	0.730
2	0.216	15.9	100.0	0.422

Tab. 6.19 - Wilks' lambda statistics of indicators for sustainability

Test of function(s)	*Wilks' lambda*	*Chi-square*	*df*	*Sig.*
1 through 2	0.384	134.587	24	0.000
2	0.822	27.508	11	0.004

The first function is evidently more significant than the other, with rather strong statistics (eigenvalue = 1.143, canonical correlation = 0.730, Sig. < 0.001, chi-square value = 134.587). In particular, this function is able to explain more than half (53.29%) of the variability within the clusters of sustainability (indeed, $0.73^2 = 0.5329$). In this case, the standardised function 1 is (Eq. 5):

$$F = 0.287 * \mathrm{HABITAT\_INADEG} + 0.166 * \mathrm{GRASS\_PAST} + 0.569 * \mathbf{WOOD\_FARM} - 0.047 * \mathit{GEOBOTVAL\_HIGH} + 0.112 * \mathit{GEOBOTVAL\_LOW} - 0.139 * \mathrm{FOR\_WOODS} + 0.500 * \mathrm{QUAL\_PROD} + 0.525 * \mathbf{TREND\_FLOOD} - 0.440 * \mathrm{PM10\_AVG} - 0.510 * \mathbf{AGR\_AREA} + 0.266 * \mathrm{LIVESTOCK} + 0.013 * \mathit{FRAGM\_PRESS} \quad (5)$$

In Eq. 5 it is possible to compare the weight of each indicator of the discriminant function. In particular, the indicators associated with the larger weights are evidenced in bold, whereas those associated to the smaller weights are in italics. Metrics related to the forests associated to farmers (0.569), to the variations of flood discharges (0.525) and to the extension of the agricultural areas (0.510) appear to have the wider discriminant weights among the other indicators. On the opposite side, the pressure exerted by anthropic infrastructures (0.013) and both the geobotanical values (0.047 for high and 0.112 for low) seem not to play a significant role in discriminating among the clusters. This might be particularly interesting, considering the significant enhancement of the statistical features of this combination achieved after the inclusion of such values.

At this point, it is possible to draw the predicted clusters of sustainability following the identification of the discriminant function. In this case, incomplete information prevented from assigning a cluster to 80 of the 229 municipalities, that are thence missing. In particular, the dataset was missing measure concerning grassland and pastures, as well as woods owned by farmers and the variation of floods. Nonetheless, the outcome evidence that 72% of the remaining *sub-units* (149 put of 229) were equally grouped by the cluster and the discriminant analysis.

6.2. Hokkaidō

6.2.1. *First phase – classification*

The analytical process performed on the indicators related to the municipalities of Hokkaidō mirrored the one previously introduced for the Marche region case. Nonetheless, the indicators were necessarily slightly differed, in order to account for the local features, also in terms of available information.

6.2.1.1. Resilience

The *resilience core* was described in terms of exposure of population, flood damages and economic effects of the flood event (Tab. 6.20).

Tab. 6.20 - Indicators and their codes per each attribute of the resilience core

Core	*Attribute*	*Indicator*	*Code*
Resilience	Learn	Population exposed to flood hazard	EXP_POP
	Absorb	Flood damages	FLOOD_DAMAGE
	Recover	Percentual difference in income after 2 years and on the year of the last flood event	TAXINCOME_1715

The procedure started from STATGRAPGICS in order to collect the initial centroids to support the further analysis in SPSS. This first set of indicators for Hokkaidō is the most closely comparable to the combination adopted for Marche, hence it is especially relevant. The centroids belonged to different quarters of the space, that remained substantially the same, even after the adjustments, that were more than in the other cases (Tab. 6.21, Tab. 6.22 and Tab. 6.23).

Tab. 6.21 - Initial centroids per each indicator and each cluster of resilience

Indicator	*Cluster*		
	1	2	3
EXP_POP	1.20256	-0.07556	-0.13888
FLOOD_DAMAGE	2.50344	-0.22082	-0.20072
TAXINCOME_1715	0.05096	-0.48871	0.66960

Tab. 6.22 - Variation in the position of the centroids per each iteration

Iteration	Changes in the centroids		
	1	2	3
1	0.587	0.078	0.248
2	0.743	0.062	0.203
3	0.000	0.030	0.135
4	0.000	0.025	0.113
5	0.000	0.028	0.159
6	0.000	0.012	0.076
7	0.000	0.012	0.083
8	0.000	0.006	0.046
9	0.000	0.000	0.000

Tab. 6.23 - Final centroids per each cluster and each indicator of resilience

Indicator	Cluster		
	1	2	3
EXP_POP	2.06219	-0.08964	-0.14280
FLOOD_DAMAGE	3.50201	-0.16565	-0.15159
TAXINCOME_1715	-0.07531	-0.24922	1.71527

Indeed, the three clusters were easily distinguishable in the graphic representation (Fig. 6.3).

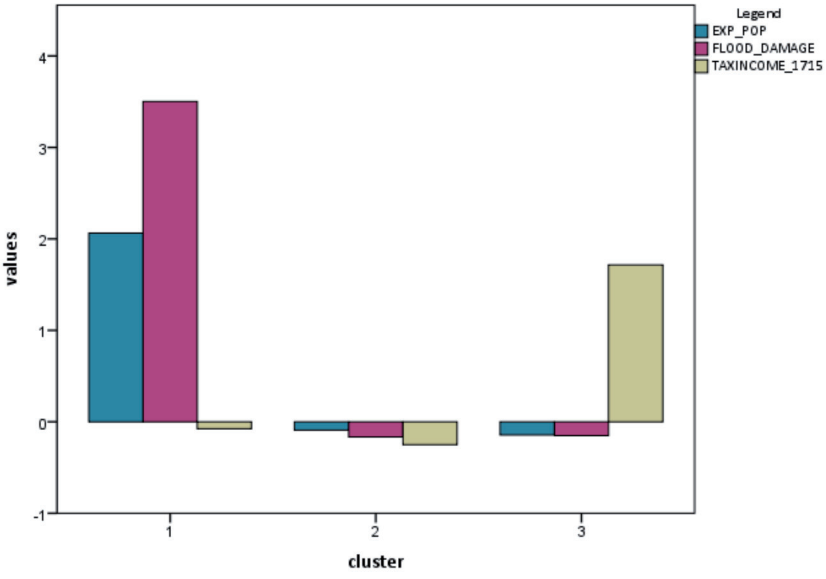


Fig. 6.3 - Bar graph of the final centroids per each cluster and each indicator of resilience

The statistical significance of the indicators was confirmed also in this case (sig. < 0.001 for all indicators), whereas the differentiating power of the indicators was not homogeneously distributed, being the indicator related to flood damages the most relevant (120.039) between the others (Tab. 6.24).

Tab. 6.24 - ANOVA table

Indicator	*Cluster*		*Error*		*F*	*Sig.*
	Mean Square	*df*	*Mean Square*	*df*		
EXP_POP	17.833	2	0.809	176	22.052	0.000
FLOOD_DAMAGE	51.353	2	0.428	176	120.039	0.000
TAXINCOME_1715	37.014	2	0.591	176	62.655	0.000

Eventually, the composition of the cluster was revealed to be uneven, with cluster 2 holding the wider portion (149 out of 179) of the municipalities (Tab. 6.25).

Tab. 6.25 - Number of cases (municipalities) per each cluster of resilience

Cluster	1	8
	2	149
	3	22
Cases	Valid	179
	Missing	0

6.2.1.2. Sustainability

The *sustainability core* was associated to indicators representing the area extension of the altered vegetation, the occupation in the power supply system and the percentage of area distribution of the raccoon (Tab. 6.26).

Tab. 6.26 - Indicators and their codes per each attribute of the sustainability core

Core	*Attribute*	*Indicator*	*Code*
Sustainability	Functions	Percentage of altered vegetation area	ALT_VEG_PERC
	Services	Employees in power supply	POW_EMP
	Integrity	Percentage of raccoon (浣, *araiguma*) distribution area	ARAIG_PERC

This combination underwent a relatively short cycle of iterations that stabilised the clusters (Tab. 6.27), not affecting much the distribution of the centroids in the space (Tab. 6.28 and Tab. 6.29).

Tab. 6.27 - Initial centroids per each cluster and each indicator of sustainability

Indicator	*Cluster*		
	1	2	3
ALT_VEG	0.57629	-0.44328	0.60255
POW_NUM	-0.49600	-0.22126	1.40277
ARAIG_AREA	1.27687	-0.49087	-0.23097

Tab. 6.28 - Variation in the position of the centroids per each iteration

Iteration	*Changes in the centroids*		
	1	2	3
1	0.378	0.086	2.449E-6
2	0.231	0.051	0.000
3	0.094	0.021	0.000
4	0.000	0.000	0.000

Tab. 6.29 - Final centroids per each cluster and each indicator of sustainability

Indicator	*Cluster*		
	1	2	3
ALT_VEG	1.09080	-0.41869	0.60255
POW_NUM	-0.55821	-0.24587	1.40277
ARAIG_AREA	1.72754	-0.34437	-0.23097

Indeed, the centroids and thus the clusters were easily distinguishable even in a graphic representation (Fig. 6.4).

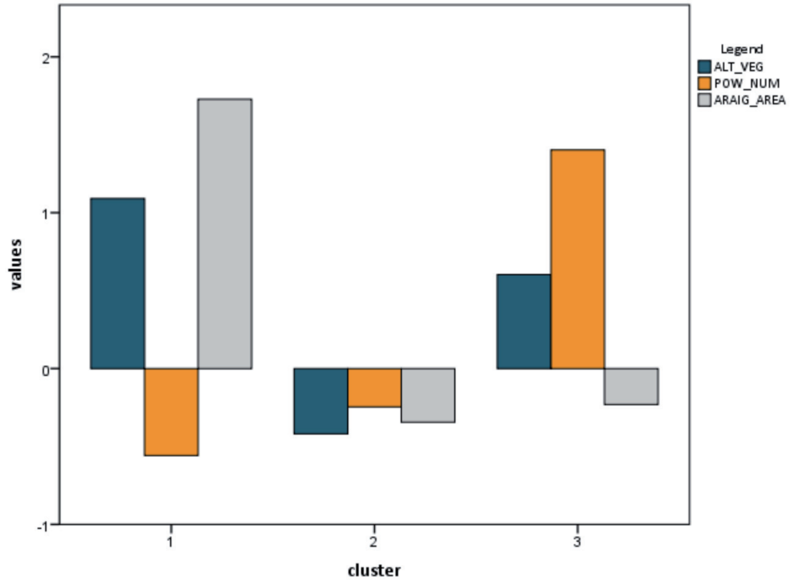


Fig. 6.4 - Bar graph of the final centroids per each cluster and each indicator of sustainability

All the indicators resulted statistically significant in drawing the clusters (sig. < 0.001 for all indicators) and their potential is relatively high, with the maximum value (111.244) associated to the distribution of alien species in the area (Tab. 6.30).

Tab. 6.30 - ANOVA table

Indicator	*Cluster*		*Error*		*F*	*Sig.*
	Mean Square	*df*	*Mean Square*	*df*		
ALT_VEG	32.897	2	0.638	176	51.601	0.000
POW_NUM	39.444	2	0.563	176	70.042	0.000
ARAIG_AREA	49.691	2	0.447	176	111.244	0.000

Eventually, the municipalities were mainly allocated in the second cluster (119 out of 179), although the remaining were almost evenly distributed between the two other clusters (Tab. 6.31).

Tab. 6.31 - Number of cases (municipalities) per each cluster of sustainability

Cluster	1	28
	2	119
	3	32
Cases	Valid	179
	Missing	0

6.2.2. *Second phase – characterisation*

The second phase adopted further indicators to describe the *dimensions* of the *resilience* and *sustainability cores*, based on the output of the previous analysis. The process was performed by means of SPSS tools.

6.2.2.1. Resilience

The selected indicators covered the demographic, social, economic, health and infrastructural facets of a community (Tab. 6.32). Similarly to a previous case, also this set of indicators include two metrics for the same "*sub-dimension*" (see the subscription to both TV and satellite broadcast). Nevertheless, also in this case the two indicators are not related, hence the requirement of mutual independence is granted.

Tab. 6.32 - Indicators and their codes per each dimension of the resilience core

Dimension	*Indicator*	*Code*
Demographic	percentage of immigrants	IMMIGR_PERC
	percentage of population over 65 y.o.	POP_OVER65_PERC
	percentage of female population	POP_FEM_PERC
	population density	POP_DENS
Social	percentage of population with compelled education	COM-PEL_EDU_PERC
	TV broadcast subscription per 1000 people	TV_SUBSCRIPT_POP
	satellite broadcast subscription per 1000 people	SAT_SUBSCRIPT_POP
	public halls and similar facilities per person	PUBL_HALL_POP
	public and private sport facilities	SPORT_FAC
Economic	percentage of employment	EM-PLOYED_POP_PERC
	taxable income	TAX_INCOME
	expenditure for social welfare	SOC_EXPENSE
	percentage of inflow population living in the same or another Prefecture	IN-FLOW_TOT_PERC
Health	nursing care facilities for the elderly	NURS_FAC
	hospital beds per 1000 people	HOSP_BEDS_POP
	doctors in medical facilities	MEDFAC_DOCT
	firefighting expenses (municipal finance) in 1000 yen	FIRE-FIGHT_EXPENSE
Infrastructural	disaster recovery expenses per person in yen	DIS-REC_EXP_PROCAP
	extension of municipal roads/population	ROAD_LENGHT_POP
	percentage of population served by septic tank	SEPTTANK_PERC
	average building construction year	AVG_BUILD_AGE

At this point it is possible to evaluate the statistical tests performed by the analytical procedure in SPSS (Tab. 6.33 and Tab. 6.34).

Tab. 6.33 - Eigenvalue statistics of indicators for resilience

Function	*Eigenvalue*	*Percentage of variance*	*Cumulative percentage*	*Canonical correlation*
1	4.368	77.2	77.2	0.902
2	1.290	22.8	100.0	0.751

Tab. 6.34 - Wilks' lambda statistics of indicators for resilience

Test of function(s)	*Wilks' lambda*	*Chi-square*	*df*	*Sig.*
1 through 2	0.081	95.334	42	0.000
2	0.437	31.480	20	0.049

To begin with, both discriminant functions were statistically significant (Sig. < 0.05 for both), though function 1 was particularly strong in this test (Sig. < 0.01). Function 1 provided also a rather high canonical correlation (0.902) and was particularly efficient in explaining the differences in the clusters (cumulative percentage = 77.2%). In general, function 1 performed rather well also the other tests (eigenvalue = 1.368, Wilks' lambda = 0.081, Chi-square = 95.334).

In light of these observations, this combination was deemed robust and reliable to proceed in the analytical process. Following, the standardised discriminant function 1 is (Eq. 6):

$$\begin{aligned}F = {} & 0.081 * \mathrm{IMMIGR\_PERC} - 0.195 * \mathrm{POP\_OVER65\_PERC} + 0.578 * \mathrm{POP\_FEM\_PERC} - \\ & 1.106 * \mathrm{POP\_DENS} - 0.306 * \mathrm{COMPEL\_EDU\_PERC} + 0.004 * \mathit{TV\_SUBSCRIPT\_POP} - \\ & 0.207 * \mathrm{SAT\_SUBSCRIPT\_POP} - 0.393 * \mathrm{PUBL\_HALL\_POP} + 0.694 * \mathrm{SPORT\_FAC} - \\ & 0.602 * \mathrm{EMPLOYED\_POP\_PERC} + 0.908 * \mathrm{TAX\_INCOME} - 24.234 * \mathbf{SOC\_EXPENSE} + \\ & 0.422 * \mathrm{INFLOW\_TOT\_PERC} + 2.412 * \mathrm{NURS\_FAC} - 0.410 * \mathrm{HOSP\_BEDS\_POP} + \\ & 18.369 * \mathbf{MEDFAC\_DOCT} + 3.815 * \mathbf{FIREFIGHT\_EXPENSE} + 0.051 * \\ & \mathit{DISREC\_EXP\_PROCAP} + 0.056 * \mathit{ROAD\_LENGHT\_POP} + 0.498 * \mathrm{SEPTTANK\_PERC} + \\ & 0.253 * \mathrm{AVG\_BUILD\_AGE}\end{aligned} \tag{6}$$

In Eq. 6, the indicators that hold the most significant discriminating power are highlighted in bold, whereas those that contributed the least to the description of the clusters are evidenced in italics. Hence, it is possible to observe how the investments on social welfare, the presence of doctors and the expenses devoted to first respondents held a pivotal role in terms of discrimination (coefficients equal 24.234, 18.369 and 3.815, respectively). On the opposite side, subscriptions to TV broadcasting services, the expenses allocated for disaster recovery and the extension of road infrastructure were not particularly significant (weights: 0.004, 0.051 and 0.056, respectively).

Lastly, it was possible to compare the cluster of resilience assigned by the previous cluster analysis to those that predicted by the selected discriminant function. In this case, the process was able to predict the cluster of a rather reduced portion of the municipalities (51 out of 179) due to the limited information available in terms of average age of built structures. Nevertheless, the results showed a complete correspondence among the assigned and predicted values (51 out of 51 municipalities, 100%). Indeed, for each (considered) municipality, the discriminant function proved able to provide the same result of the cluster analysis. It might be noteworthy that such performance was granted for all 3 clusters, each of that found a representation in such restricted sample.

6.2.2.2. Sustainability

Lastly, the discriminant analysis was performed for the *sustainability core*. As mentioned, the selection of indicators suffered from limited data availability (Tab. 6.35).

Tab. 6.35 - Indicators and their codes per each dimension of the sustainability core

Dimension	*Indicator*	*Code*
Ecosystems integrity	forests extension	FOREST_AREA
	grasslands extension	GRASS_AREA
	extension of wildlife sanctuary	WLDLF_SANCT
Ecosystem benefits	private forests	PRIV_FOREST
	fisheries and aquaculture entities	FISH_ACQCUL
Physical processes state	water intake of water supply businesses per person	WAT_INT_POP
	difference from optimal pH value in river water	WAT_QUAL
External pressures	cultivated land area	AGRIC_AREA
	revenue from beef cattle	BEEFCATTLE_REV

Following, the SPSS statistical tests could be run to evaluate the robustness of the combination (Tab. 6.36 and Tab. 6.37).

Tab. 6.36 - Eigenvalue statistics of indicators for sustainability

Function	*Eigenvalue*	*Percentage of variance*	*Cumulative percentage*	*Canonical correlation*
1	0.545	90.2	90.2	0.594
2	0.059	9.8	100.0	0.237

Tab. 6.37 - Wilks' lambda statistics of indicators for sustainability

Test of function(s)	*Wilks' lambda*	*Chi-square*	*df*	*Sig.*
1 through 2	0.611	46.806	18	0.000
2	0.944	5.479	8	0.705

It is possible to observe how the statistical significance was granted only for function 1, though very high (sig.< 0.001, with a 95% of confidence); the overall discriminant potential was rather promising (0.594). The canonical correlation allowed to estimate a discriminant potential of about 35.3% ($0.594^2 = 0.353$), meaning that function 1 would be able to explain about the 35% of the variation among the clusters of sustainability. Although it might be not particularly high, this function showed a considerable eigenvalue (0.545) and a relative discriminant power (variance = 90.2%) and a reasonably high chi-square value (46.806).

Consequently, the final step of the analytical procedure revolved around this function, drawing the related standardised equation (Eq. 7):

$$F = 0.923 * \mathbf{FOREST\_AREA} - 0.490 * \mathbf{GRASS\_AREA} + 0.338 * \mathrm{WLDLF\_SANCT} - 0.309 * \mathit{PRIV\_FOREST} - 0.242 * \mathit{FISH\_ACQCUL} - 0.325 * \mathrm{WAT\_INT\_POP} + 0.390 * \mathrm{WAT\_QUAL} + 0.730 * \mathbf{AGRIC\_AREA} + 0.020 * \mathit{BEEFCATTLE\_REV} \quad (7)$$

The most relevant indicators in terms of discriminating power are evidenced in bold in Eq. 7, while the least influencing indicators are highlighted in italics. It might be noteworthy that the first (weight: 0.923) and third (weight: 0.490) most powerful indicators were related to the extension of forests and grasslands. The second most significant indicator (weight: 0.730) was related to the extension of the agricultural area, hence eventually the function was dominated by metrics referred to the presence of vegetation, both wild and cultivated, in the municipalities. On the opposite side, the indicators that held the most limited discriminant power (weight: 0.020) were associated to the profits stemming from beef farming, followed by the enterprises engaged in fisheries and aquaculture as well as the extension of cultivated woods (weight: 0.242 and 0.309, respectively), although the potential of these last two indicators was more comparable to the others.

At this point it was possible to proceed towards the last phase of the analysis, that concerns the verification of the actual accuracy of the discriminant function in identifying the cluster of each municipality. Also in this case, the incomplete dataset did not allow to perform the test for all the municipalities, although a rather high portion was included (102 out of 179 municipalities). In particular, here the most critical information concerned water quality and the revenues from beef cattle. Nevertheless, it was still possible to estimate the predictive accuracy of the discriminant function. Indeed, it appeared quite appreciable, as the majority of the municipalities (71 out of 102, that is 70%) were allocated to the same cluster by the cluster and the discriminant analyses. These observations conclude the presentation of the results of applying the proposed methodology to the selected case studies.

7. *Discussion*

The methodology proposed within this research framework was developed in order to investigate the condition of disaster resilience and of environmental sustainability. The results of its application on two case studies, the Marche region and the Hokkaidō, were presented above. At this point it is possible to proceed towards the interpretation of the delivered outcomes, especially examining the results through the lenses of the panarchy paradigm. Also in this case, the following paragraphs will consider separately each case study, per each phase of the methodology and per each *core*. Lastly, some considerations will bring together the overall gained perspective.

7.1. Marche region

7.1.1. *First phase – classification*

7.1.1.1. Resilience

The first phase of the process performed a cluster analysis, as mentioned above. A pivotal part of such analysis is played by the centroids, as they define the centres of the clusters, thence the differentiation among the groups. In this case, the initial centroids already belonged to different quarters of the space defined by the indicators, though the adjustment introduced by the k-means clustering enhanced a more evident distance in the final centroids (Tab. 6.3, Tab. 6.4 and Tab. 6.5), hence suggesting a more efficient separation among the clusters. This is a desirable condition, since the more the clusters are far from each other and the more evident is the difference in the characteristics of their composing elements, in this case in the disaster behaviour of the municipalities. Additionally, the cycle of iterations needed to adjust the positions of the centroids resulted rather brief, thus suggesting a high stability, and consequently reliability, of the grouping. Indeed, all indicators resulted significant and efficient in differentiating the clusters, with two of them (the economic-related indicators) exhibiting comparable weights, although none of them overwhelming the others (Tab. 6.6). As a consequence, it appears that the selected indicators were appropriate to describe their capacities in terms of disaster resilience and their combination was rather balanced. Thence, the distribution of the municipalities between the three clusters might be assumed as reliable (Tab. 6.7).

At this point, it is crucial to address the issue of associating each cluster to a level of resilience. In this regard, the bar graph might be especially beneficial (Fig. 6.1). In the graph, each cluster is represented by related centroids, in terms of values of the three indicators (Fig. 7.1). In particular, values above the baseline represent a relative increase, whereas below the baseline suggest a decrease. In terms of most desirable conditions, it might be argued that that higher levels of resilience would correspond to: first, a reduction of the level of exposure, since the less population is susceptible and the lower the flood risk, that is the less probability of suffering losses; second, the least possible amount of fund allocated to disaster recovery, as it would mean that the amount of damages were limited; third, an increase of revenues, as the possibility to rely on consistent assets should grant the possibility to prepare before and cope after the strike of threatening events.

Here, cluster 1 is characterised by a decrease in the population exposed to flood hazard and in the amount of recovery funds received by the municipality, and an increase in the taxable income two years after the events. Cluster 2 exhibits a decrease in the population exposed, a negligible amount of resources allocated to flood recovery and an evident decrease of the local income. Lastly, cluster 3 shows a marked trend in exposed population and received funds for disaster recovery, while the taxable income is clearly diminishing. In light of the above considerations, the trend from cluster 1 to cluster 3 appear to represent decreasing levels of disaster resilience. Indeed, the cluster 1 appears to embody the most desirable conditions of low susceptibility and wider coping capacities, whereas the cluster 3 stands on the exact opposite side, with high potential to suffer from disasters and limited assets to face them. In the middle, the cluster 2 shows a low exposure of population, similarly to cluster 1, and a decrease in the income, similarly to cluster 3, while the damages are not relevant. The association of the levels of resilience to the clusters seems rather solid, hence there is no need to further investigate the theme on the basis of the weights of the indicators. Consequently, it is possible to assign the high level of resilience (HR) to cluster 1, the medium level (MR) to cluster 2 and the low level (LR) to cluster 3 (Fig. 7.1).

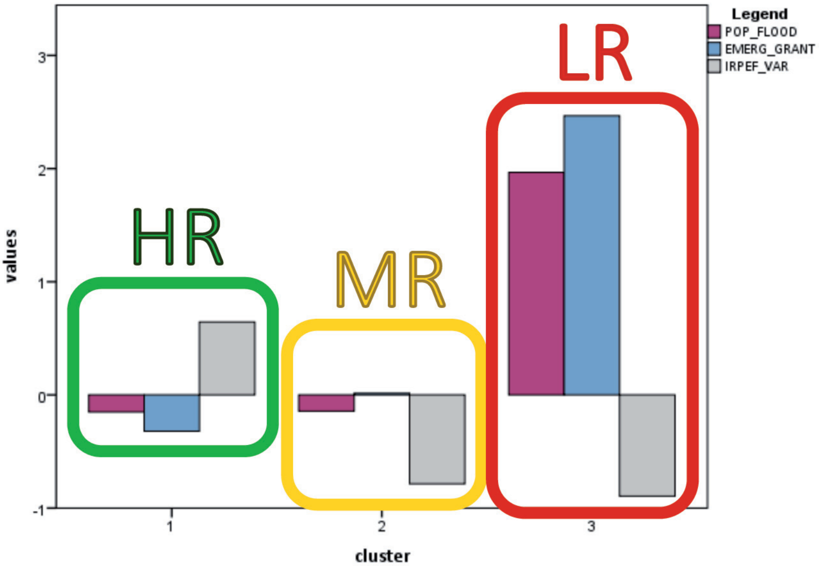


Fig. 7.1 - Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of resilience (R)

As a consequence, it appears that most of the municipalities (127 out of 229) of the Marche region, belonging to cluster 1, shows to the highest level of resilience, while the remaining are mainly included in medium level (86) and only a limited portion of the municipalities (16) are associated to the lowest level (Tab. 7.1).

Tab. 7.1 - Distribution of the municipalities of Marche region between the clusters and the levels (high H, medium M, low L) of resilience (R)

Cluster	*Level of resilience*	*Number of municipalities*
1	HR	127 (55.46%)
2	MR	86 (37.55%)
3	LR	16 (6.99%)

Overall, it appears the Marche region holds a promising potential in terms of capacities to face and cope with a flood event. Indeed, the analysis allowed to compare the disaster behaviour of the municipalities and it emerged that more than half (55.46%) performs considerably better than the others and, in parallel, only a limited share of the municipalities (6.99%) might require a significant enhancement of the local capacities. At the same time, the municipalities showing a medium level of resilience should not be overlooked. Although it is encouraging that they stand in a balanced condition, this also suggests that improvements might consolidate and further improve the local resilience approach.

At this point, it might be interesting to visualise the distribution of the levels of resilience throughout the region (Fig. 7.2).

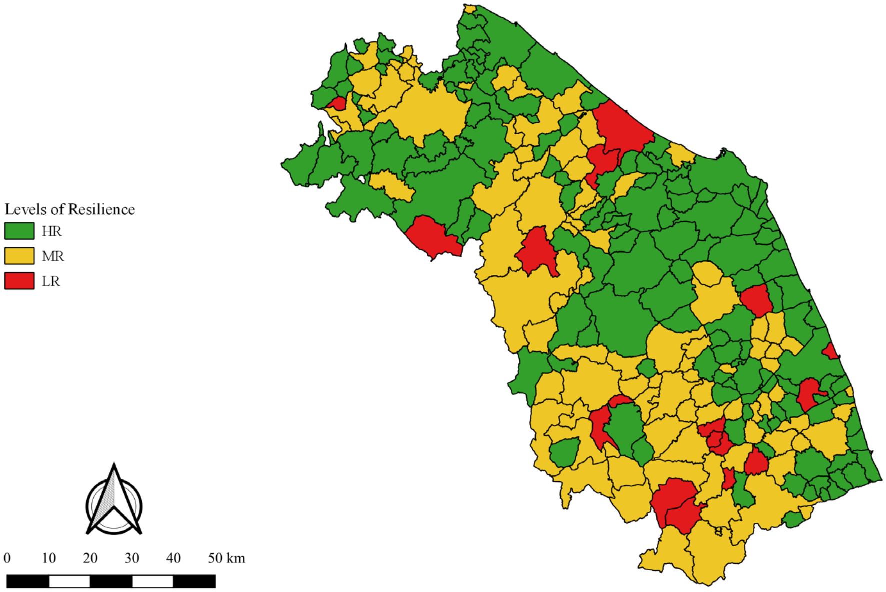


Fig. 7.2 - Distribution of the levels (high H, medium M, low L) of resilience (R) among the municipalities of the Marche region

The levels of resilience appear evenly distributed over the region, although it might be possible to identify some approximative alternation of homogeneous groups of medium and high levels proceeding from North to South, dotted by the lowest levels. Indeed, the grouping does not seem to be based on the morphological features of the region (e.g. lowest levels in the western mountainous area), even though it might be noteworthy that indeed most of the municipalities laying along the coast are associated with the highest level of resilience, with few exceptions: Gabicce Mare, Falconara Marittima, Pedaso and Massignano (MR), and Senigallia and Porto San Giorgio (LR). Rather, the emerging distribution appears to gather municipalities along an almost horizontal axis. This directrix resembles that of the hydrographic network and thence of the river basins (Fig. 7.3).

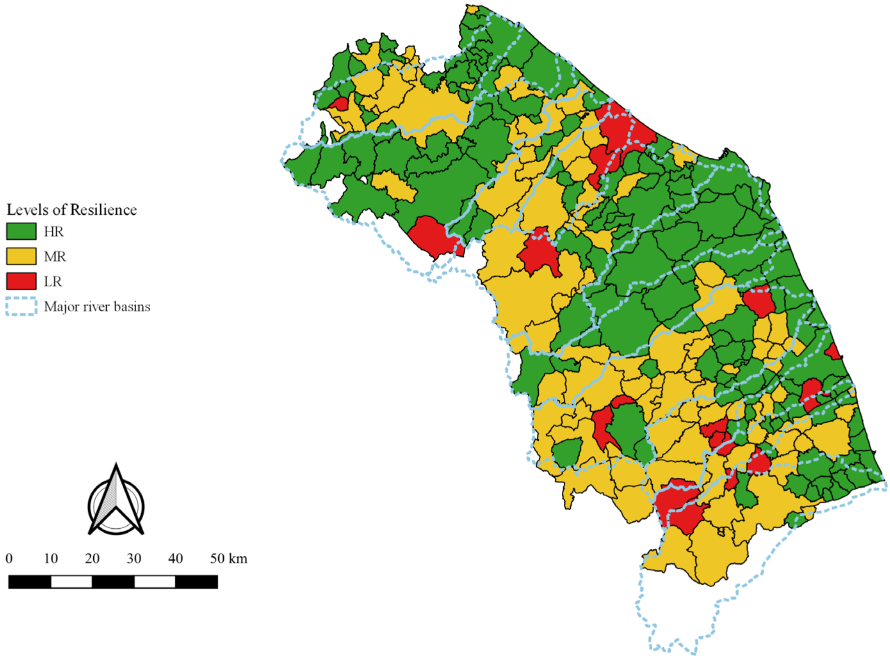


Fig. 7.3 - Distribution of the levels (high H, medium M, low L) of resilience (R) and of the river basins of the Marche region

It might be interesting to observe that the river basins of the Marche region appear overall homogeneous in terms of disaster behaviour related to flood risk, with average medium or high levels of resilience characterising each basin. The most exemplificatory case is that of the Musone river basin (central section of the region), that is exclusively composed of municipalities associated with the highest level of resilience. The few exceptions are represented by the basins related to the Foglia, Esino and Chienti rivers, that appear more heterogenous. This feature might be relevant in terms of flood impact and management. Indeed, one indicator of the cluster analysis was related to flood damages, and it held a relevant differentiating power, hence the consistent characterisation might inform on the effectiveness of the strategy enacted along the rivers. At the same time, differences might be due to some specific features, that might hint at other ongoing processes in the local areas. For instance, the indicator related to the distribution of population might maintain record of local socio-demographic dynamics such as the migration from the mountainous areas to the coast. Similarly, it might be possible to trace those trends through the indicator related to the personal income. Indeed, the employed indicators mirror such a composite condition. Although the cluster analysis evidenced the higher differentiating power of the economic-related indicators, concerning the amount of damages and the recovery of the household capacities in the short term, when looking back at the distribution of their quantification among the municipalities, it appears challenging to trace a definite trend that would clearly separate between the groups. In addition, the indicator related to the exposed population contribute to blur the examination, thus further limiting the possible identification of the major differentiating traits and suggesting a complex, multifaceted reality. At the same time, it might be noteworthy that the Marche region underwent some severe events in the assumed period for the present investigation. In particular, Central Italy was involved in a seismic sequence that included two disruptive earthquakes, on 24th August and on 30th October 2016, characterised by a magnitude of 6.0 Mw and 6.5 Mw respectively (INGV, 2017). The Marche region severely suffered from the events: the affected area extended for 3978 km^2 (approximately 42.32% of the regional territory), where 31714 people (2.08% of the overall population) were involved (Regione Marche, n.d.-b). Given the dreadful consequences that concerned the local territories, it might be expected that the overall resilience of those municipalities was hindered. Even though the quantification of the indicators employed for the cluster analysis might be influenced by wider, more complex processes that are not exclusively flood-related, the outcome of the cluster analysis might still be valid, as those processes affected also the local capacities to cope with flood risk. For instance, local authorities might have diverted a relevant amount of resources from risk management to recovery funds, hence hampering the overall risk preparation strategies. At the same time, citizens might have been affected by the earthquake, thus losing assets and resources to face other threats. Indeed, this might confirm that when dealing with disaster resilience, the social-ecological system has a complex behaviour that is influenced by a series of factors, some of which unpredictable, as the occurring of an earthquake. In other words, what occurs at a certain scale of the social-ecological system might indeed influence and undermine the stability of other scales, triggering a cascade of consequences that might reach even unrelated areas.

7.1.1.2. Sustainability

Also this case, the centroids of the clusters were rather stable, as only three iterations were necessary in order to stabilise their positions, that anyway remained almost unaltered and well differentiated (Tab. 6.9, Tab. 6.10 and Tab. 6.11). Consequently, it might be assumed that the clustering of the municipalities based on their environmental sustainability was rather consistent, thence suggesting that the employed indicators were appropriately sorted to describe this *core*, also considering their statistical significance. Nonetheless, their potential in separating the groups was not equal. In this case, the alterations to natural landscapes played the most significant role, followed by the critical conditions of flora and fauna, whereas the amount of abducted water for anthropic use was only marginal (Tab. 6.12).

At this point, it is possible to investigate the distribution of the levels of sustainability among the municipalities and throughout the Marche region. In this case it was assumed that a high rate of natural land converted to urbanised and industrialised areas would be detrimental for the local sustainability, as the potential of natural ecosystems to perform their functions would be limited by the disappearance of natural landscapes. Similarly, an increase in the quantity of abducted water for anthropic uses would be unfavourable, as it would imply a substantial human impact on the natural systems, thus potentially undermining their equilibria. Lastly, a considerable presence of species in unfavourable conditions would be an evident sign of unhealthy conditions of the natural ecosystems. Recalling the bar graph representing the clusters through their centroids (Fig. 6.2), cluster 1 exhibits a decrease in all the indicators, suggesting a lower portion of regional area converted in anthropic landscapes, higher amount of clean water abducted from natural sources and less threatened species. Cluster 2 shows rather different features: although the conversion of land is limited, the quantity of natural water and of endangered species tends in the opposite direction, with an evident increase. Lastly, the trend is reversed for cluster 3, that displays a marked increase of conversion from natural to urbanised and industrialised areas, while the rate of abducted water and of species in unfavourable conditions is among the lowest. As a consequence, in this case cluster 1 is assumed to represent the highest level of sustainability (HS), whereas cluster 2 is associated to the medium level (MS) and cluster 3 the lowest level (LS) of sustainability (Fig. 7.4). While the identification of the HS might be almost intuitive, the other levels might require some further considerations, as the trends of the indicators are not consistent hence it is not possible to draw a univocal interpretation.

In this case, the weights of the indicators might help to shed some light. The indicator related to the land take holds the higher weigth compared to the other indicators, hence the most discriminating power should be associated to this indicator, followed by the indicator concerning the condition of animal and vegetable species. Consequently, as cluster 3 shows a significant increase in the conversion of natural land, with the other indicators closer to an invariance, it is associated to the lowest conditions in terms of sustainability. On the contrary, cluster 2 is significantly less concerning in terms of alteration of natural areas, although the conditions are still not ideal, as the other features tend towards unfavourable conditions, thence the attribution of the medium level of sustainability. It is acknowledged here that in this case the role of the researcher is pivotal. Evidently, here the correspondence among clusters and levels of sustainability is a matter of interpretation, though possibly aided by the weights associated to each indicator, that being an objective parameter.

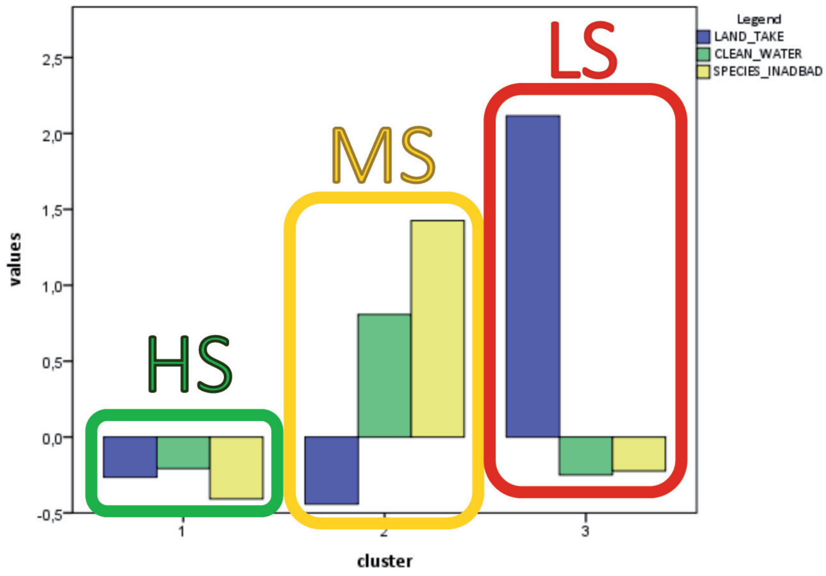


Fig. 7.4 - Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of sustainability (S)

Nonetheless, assuming the validity of these considerations, it might be possible to associate the municipalities to the corresponding level of sustainability (Tab. 7.2). It appears that the majority (152 out of 229) of the municipalities is associated to the highest level of sustainability, while the second most populated level (48) is the medium, eventually followed (29) by the lowest level.

Tab. 7.2 - Distribution of the municipalities of Marche region between the clusters and the levels (high H, medium M, low L) of sustainability (S)

Cluster	*Level of sustainability*	*Number of municipalities*
1	HS	152 (66.38%)
2	MS	48 (20.96%)
3	LS	29 (12.66%)

Following this distribution, it appears that the environmental sustainability of the municipalities of the Marche region is rather encouraging, as a considerable portion (66.38%) exhibits the most desirable conditions. This is further confirmed by the rather limited portion of the municipalities (12.66%) that might require a significant enhancement sustainability. In other words, it appears that the region is overall characterised by favourable conditions, dotted by more fragile spots. In this regard, a geographical visualisation of the situation might be beneficial to draw some interesting insights (Fig. 7.5).

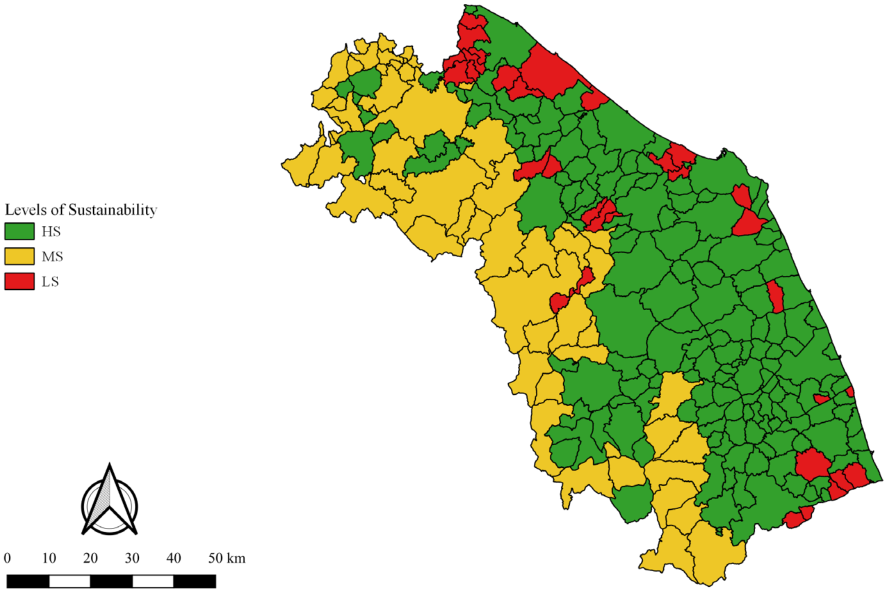


Fig. 7.5 - Distribution of the levels (high H, medium M, low L) of sustainability (S) among the municipalities of the Marche region

The municipalities appear rather well differentiated in two parallel bands, one for HS and one for MS, directed from North-West towards South-East. It might be noteworthy that the municipalities that exhibits the less desirable conditions are often aggregated into pockets of 2 to 7 elements, that punctuate those bands, mostly the one corresponding to the higher level of sustainability, and are generally shifted towards the eastern side. The distribution of the bands seem to follow the morphological features of the region, that is characterised by mountains in the western area that progressively decline in hills and eventually reach the coastline in the eastern side, while being crossed by narrow river plains (Fig. 7.6).

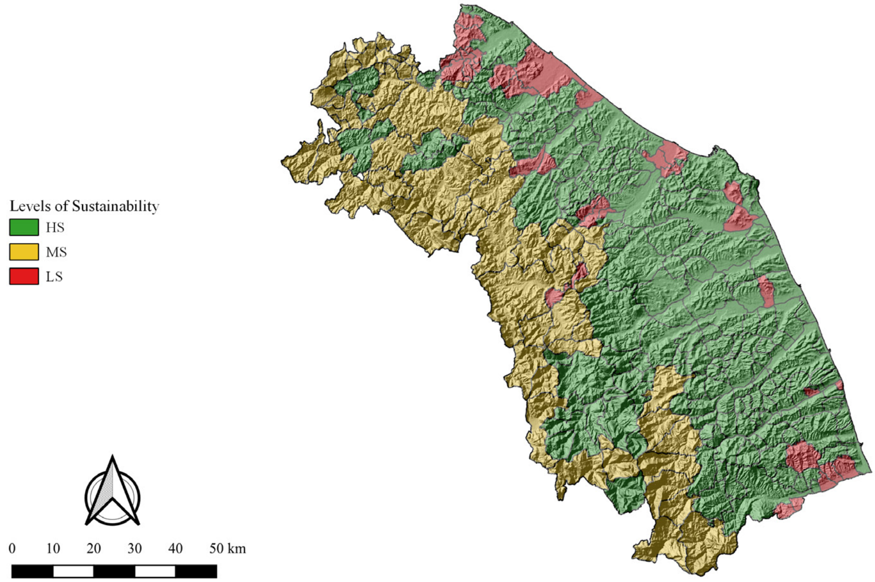


Fig. 7.6 - Distribution of the levels (high H, medium M, low L) of sustainability (S) and the morphological features of the Marche region

Observing the morphology of the Marche region, it emerges an overall lower performance of the mountain areas in terms of sustainability, as the medium level is distributed along the Appennini chain, with better performing municipalities constituting some pockets in the Pesaro-Urbino Province and in the area of the Macerata Province, then extending throughout the hill area towards the coasts. As mentioned, the least desirable conditions are exhibited by small groups of neighbouring municipalities, mainly disseminated around the estuaries and partly along the river plains, especially the Metauro, Cesano, Esino and Tronto rivers. This distribution might be surprising, considering that the inner territories have implemented substantial strategies to foster the protection of the environment, for instance promoting the preservation of wildlife through protected areas, such as the "*Parco Nazionale dei Monti Sibillini*" and the "*Parco Nazionale del Gran Sasso e Monti della Laga*" in the south-western corner of the region, and the "*Parco Naturale Regionale della Gola della Rossa e di Frasassi*" in the central area, which are the widest in the Marche region (Regione Marche, n.d.-a). These protected areas are subjected to a specific regulation, aimed at limiting the human impact on the natural systems and thence contribute to the enhancement of the local conditions of the ecosystems. In light of the outlined clusters, it might appear that those strategies were not sufficient to achieve the most desirables attributes of sustainability, thus some improvements might be encouraged. Furthermore, it might be noteworthy that similar initiatives were enacted also in the coastal areas, such as the "*Parco Naturale Regionale del Monte San Bartolo*" in the northern part and the "*Parco Naturale Regionale del Conero*" in the central part of the region, though they appear to lay in the most advantageous conditions in terms of sustainability. One of the most relevant consequences of the protected areas concern the zoning of the pertaining area based on the allowed human activities and transformations of the local landscapes (*Legge Quadro Sulle Aree Protette 6 Dicembre 1991 n. 394*, 1991). Since in this case the conversion of natural environments into urban and industrial areas is a determining factor in differentiating the behaviour of the municipalities, it appears that the beneficial influence of the protected areas might be failing to extend to the overall municipality. Indeed, when examining the quantification of the indicators among the municipalities, the effect of the conversion of natural environments into anthropic areas emerges especially effective in identifying the least desirable conditions of sustainability. On the contrary, the picture becomes relatively blurred between the two other clusters. In this case, though, it is possible to observe that the conditions of species in the municipalities associated to the intermediate levels of sustainability are generally significantly worse. In addition, when examining the most desirable conditions, it seems that the lower performances in terms of land take were more efficaciously compensated by better results specifically in terms of protection of local species. In other words, it seems that the pockets of low sustainability along the coasts might be specifically due to the heavy impacts of anthropic processes that alter the natural environment, hence tailored activities might be planned to reverse this detrimental trend. At the same time, the inner territories might benefit from a strengthening of the protected areas, consolidating the efforts to preserve native species.

Here in particular, local socio-demographic dynamics might have influenced the outcome leading to the less encouraging performances. For instance, the abandonment of agricultural activities might have prompted a more substantial transformation for urban or industrial purposes of the inner territories, especially compared to the coastal areas, traditionally more developed, thence possibly more stable in terms of land use change. Overall, this situation appears to suggest that the protection of natural areas should be encouraged on a wider basis, in order to foster a general and sounder coexistence with the natural ecosystems. Such an approach would also influence both the pivotal indicators, related to the conditions of the local ecosystems. Indeed, the protection of the local natural environments might positively affect the state of flora and fauna, thence enhancing the mutual interactions of the anthropic and of the natural components of the local social-ecological system.

7.1.2. *Second phase – characterisation*

7.1.2.1. Resilience

The second phase of the analytical procedure used a further set of indicators in order to describe the different *dimensions* of the *resilience core*. Among the different combinations that were tested, one was selected as the most effective. In particular, the potential to discriminate among the clusters resulted the highest along with a satisfactory statistical significance (Tab. 6.15 and Tab. 6.16). Though these metrics are encouraging, the estimated discriminant power appears not particularly high. That is, the discriminant function can explain a limited part of the variations occurred between the 3 clusters of resilience. This might suggest that although the indicators described a wide range of characteristics of the local communities, some relevant traits might have been missed. Consequently, including a wider range of variables might turn beneficial to enhance the overall performance of the function.

The indicators describing the presence of women and of elderly appeared especially significant in determining the assigned cluster and thence the level of resilience of the municipalities, followed by the volunteers engaged in no-profit organisations (Eq. 4). This is particularly relevant, as demographic variables have traditionally been included in the assessments of resilience and the presence of women and elderlies are commonly considered an inherent factor that influences the ability to cope with disasters (see e.g. Cutter et al., 2010; Kadir, 2021). The emergence of the volunteers, though, is partially unexpected, as this kind of variable is not always included in resilience assessments. Nevertheless, no-profit organisations are typically devoted to the enhancement of the local community, enriching it either through cultural activities or social assistance. Hence, the presence of volunteers might suggest a sounder engagement of people in the improvement of their community as well as a robust social cohesion that might turn pivotal in emergency times. Despite the mentioned issue, the discriminant function was still able to deliver an appreciable assignation of the clusters. Indeed, 66% of the municipalities were associated to the same level of resilience by both the cluster and the discriminant analysis. Hence, although this performance might be consolidated through a more accurate comprehension of the specific features of the case study, the outcome is still encouraging with regards to the predictive potential of the function. Furthermore, as previously mentioned, a discriminant function not only supports the identification of the most relevant variables of a stated problem, but it also enables the monitoring of the resilience capacities of a municipality, through the changes ongoing in the municipality itself. In this case, the accuracy of such prediction still needs some refinement, but it remains a promising application.

7.1.2.2. Sustainability

The second phase of the sustainability assessment proceeded through the selection of the most appropriate function to describe the approach of the municipalities towards environmental issues (Tab. 6.18 and Tab. 6.19). In this case, the function held a significant discriminating potential, as it was able to explain around the 53% of the variability among the clusters, hence proving to be more significant compared to the resilience function. Indeed, the predicted clusters correspond to the 72% of those previously assigned by the cluster analysis, confirming the sounder performance of the sustainability function. It might be noteworthy that the number of indicators included is lower than in the resilience case, though delivering a more notable outcome. This appears to confirm that the inclusion of the appropriate variables is more meaningful than employing a wide range of general variables. It is acknowledged that the more information is supplied and the more thorough and accurate picture might be portrayed. The present experience suggests that a fundamental element consists in including the "right" variables, that can be selected and maintained for further implementations.

In addition, data availability resulted particularly critical. Indeed, a significant portion of the municipalities (80 out of 229) could not be assigned a cluster because of a lack of data. This issue hampers also the predictive potential of the function. As previously mentioned, holding a discriminant function allows to monitor the performance of the municipalities through time, relying on easy-to-access indicators. Nevertheless, the databases related to the state of the environment do not appear to receive extensive and continuous contributions. As such, it becomes challenging to even gather significant indicators, apart from undermining the overall understanding of the conditions of a social-ecological system in the long term. Despite these issues, in this case most of the pivotal indicators were related to the condition of the natural environment, especially the more pristine features (assessment of the condition of forests; geobotanical value of the area), and to the integration of human activities in that environment (areas devoted to agriculture). While these features hold a general significance, as they describe the impact of anthropic processes on environmental integrity, the other relevant indicator is related to the alterations occurring to natural physical processes, possibly due to the impact of anthropic activities, as well, but at higher scales. Consequently, this might suggest that the local sustainability is indeed a multifaced issue and that local dynamics are affected by multi-scaled processes that need to be comprised even in local assessments.

7.1.3. *Insights on local panarchy conditions*

The previous analytical processes delivered a classification in terms of disaster resilience and of environmental sustainability of the municipalities of the Marche region. Nevertheless, the Social-Ecological Panarchy suggests that such cores should work in synergy in order to foster an integrated development of local communities. Consequently, as they equally represent a pivotal element for the survivability of social-ecological systems, it might be interesting to combine the assessed levels to draw a more comprehensive representation of the Marche region. Here, the procedure simply juxtaposes the two classifications (Tab. 7.3). Notably, this process leads to the identification of the position of each municipality within their own adaptive cycle. This association further allows to visualise through the panarchy point of view the overall region (Fig. 7.7).

Tab. 7.3 - Municipalities (number and share) per combined level (high H, medium M, low L) of resilience (R) and sustainability (S) and presence in the fore-loop of the adaptive cycle

Number of municipalities	*Combined level of resilience and sustainability*	*Share of the municipalities*
88	HR-HS	38.43%
18	HR-MS	7.86%
53	MR-HS	23.14%
159	*fore-loop*	69.43%
25	MR-MS	10.92%
8	MR-LS	3.49%
5	LR-MR	2.18%
0	LR-LS	0.00%
21	HR-LS	9.17%
11	LR-HS	4.80%

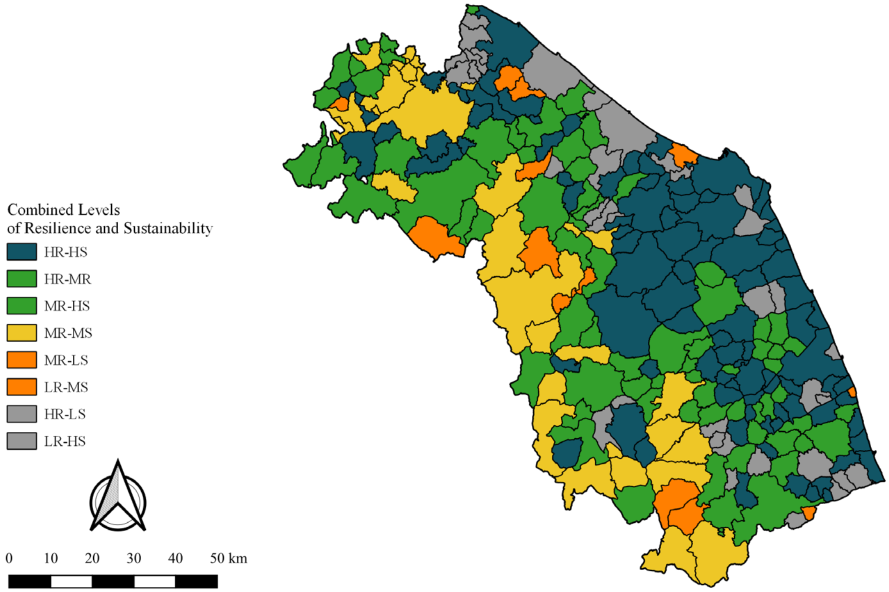


Fig. 7.7 - Distribution of the combined levels (high H, medium M, low L) of resilience (R) and sustainability (S) among the municipalities of the Marche region

The municipalities of the Marche region appear rather varied in their combined characteristics of resilience and sustainability, although it might be noteworthy that the worst combined level (LR-LS) remains unpopulated. In other words, within the present framework, all municipalities were outside the *release phase*, hence there was no identified collapse for the time considered. Rather, the wider portion of the municipalities resided within the *fore-loop* (69.43%), as the result of the three combined levels that enclose it (HR-HS 38.43%, HR-MR 7.86%, MR-HS 23.14%). In particular, the most desirable combined level (HR-HS) was rather highly populated, accounting for the highest share of the municipalities, thence delivering an encouraging perspective on the Marche region. Nevertheless, it might be relevant to observe how these municipalities appear aggregated around a main nucleus in the central-eastern area of the region, while extending with a scattered pattern southward. In general, the most desirable conditions are exhibited along the coastline, whereas the mountain and hill bands present an inhomogeneous composition. Similarly, most of the municipalities that result locked in adverse *traps* are mainly condensed in the half part of the region pointed towards the Adriatic Sea. As mentioned, such *traps* represent an overwhelming predominance of a *core* over the other. In other words, it embodies a case in which the enhancement of a resilient approach did not integrate an environmental sustainability perspective, or the opposite situation, where the management of environmental issues did not consider resilience constraints. Given this premise, the coastal area shows a significant rate of municipalities that achieved the highest performance in at least one of the two *cores*, thus suggesting that awareness and proactivity towards risk and environmental issues are commonly nurtured in this area. Conversely, flood-related questions result more complex for the mountain-hill area rather than for the coasts. This might be due to the inherent deeper fragility of those territories, both from a physical, natural and a socio-economic standpoint. In general terms, municipalities in the inner area of the region might retain fewer assets, resources and capabilities to deal with complex threats and problems, while residing in an area that is especially susceptible to suffer from their impact. Indeed, the features that primarily led to these results evidence that a significant portion of land was transformed into built-up areas, although this did not translate in a sound economic picture, but rather in a fragile context. This fragility extended to the structural domain, given the higher request and acquirement of external funds to recover from the experienced damages, as well as to the environmental domain, given the higher rate of endangered species, possibly a further cascading effect of the overall unstable conditions on the natural ecosystems. In terms of *adaptive cycles*, such municipalities stand either in the segments surrounding the *release phase*, that is the most critical section of the *cycle*, or in the curve that attempts to move past it, towards a new development course. In other words, those areas lie in more unstable and potentially unpredictable conditions, that call for a focused support to strengthen their capabilities.

Nevertheless, it is here reminded that this outcome comes from a comparative analytical procedure. That is, the above discussed municipalities are in the less desirable conditions compared to the other municipalities. Notably, that might not mean that they are on the verge of a collapse in absolute terms. Rather, this reveals the most fragile areas of the region, that might thus represent a priority when discussing where to place investments and resources. On the opposite side, the best performing municipalities are relatively more stable and promising, being comparingly closer to the *fore-loop*. Thence, they might represent a chance to comprehend the inner processes, with the aim of later tailoring to other areas. In this regard, the second phase of the analytical procedure might support the identification of the features that might be pivotal in boosting the overall conditions, through the evidence of the most significant characteristics to mould a resilient and sustainable behaviour. In this case, the presence of female and elder population appears rather relevant, but while this feature is inherent and it cannot be influenced, further attention should be given to the other pivotal factor, that is the engagement in associations. In this sense, encouraging the involvement of local communities in discussing, planning and managing local issues might strengthen social ties as well as raise the awareness on critical issues, thus enhancing a more comprehensive response capacity. At the same time, it appears fundamental to preserve natural habitats, especially forests and woods, and to limit the alterations of the natural environments, favouring lower-impact land use, as it might be agricultural activities compared to industrial settlements. Evidently, environmental changes pose a threat not only on a global scale, but also at smaller scales, and their effects, such as the alteration of precipitation patterns and thence of river dynamics, might jeopardise local equilibria. Consequently, local authorities should foster adaptation strategies, in order to strengthen the local capabilities to cope with these ongoing alterations. It might be observed that these considerations stem from an analysis focused on flood risk. As such, these understandings should apply to this specific threat. Nevertheless, the implications appear to hold a more general validity: a sounder engagement of the local populations in the development of their communities might be pivotal to foster a more attentive awareness to any kind of potential issue, as well as a thorough management of local natural processes might represent an overall stabilising factor.

7.2. Hokkaidō

7.2.1. *First phase – classification*

7.2.1.1. Resilience

Among the tested set of indicators, the preferred combination was especially relevant in terms of comparability among case studies, as it closely resembled the description adopted to assess the resilient behaviour of the Marche region. In this case, the cycle of iterations required a relatively long process to stabilise the position of the clusters. Nonetheless, the differentiation remained evident throughout the process (Tab. 6.21, Tab. 6.22 and Tab. 6.23), suggesting that it was possible to identify a significant difference among the municipalities in terms of disaster behaviour. Such an outcome is especially appreciable, as it consolidates the subsequent association to the levels of resilience: the more differentiated are the cluster, the straighter is the allocation of the municipalities. All the indicators resulted significant in determining the distribution of the municipalities among the clusters, although their weights were not homogeneous (Tab. 6.24). Indeed, the influence of flood damage resulted particularly significant, only followed by the variation in the economic welfare. The presence of human settlements within flooding areas appeared to hold a limited effect in differentiating among the groups, possibly because of enacted regulations or local habits in land-use planning and management. That is, such common traits might have normalised this feature throughout the prefecture, thus limiting its potential to distinguish different approaches. In any case, all indicators held a significant differentiating power, thence the grouping can be considered valid.

At this point it might be possible to translate each cluster in a level of resilience. Here, the bar graph (Fig. 6.3) might result especially useful. Reasonably, a higher rate of exposed population should be associated to a lower level of resilience, since it would represent an inherent vulnerability of the community, that consequently might likely suffer from an adverse event. Similarly, a higher rate of damages might suggest that the flood event overwhelmed the local abilities to cope with it, thus significantly affecting the local communities. Lastly, the variation in the economic income might hint at the recovery process after the event and in particular the extent of those effects. Indeed, the more severe the consequences, the wider effort to respond and bounce back, thus revealing the communities that held sufficient assets to face the challenge.

Here, it appears that cluster 1 represents the condition of higher exposition of population to flooding, the widest damages after the flood and a minor decline in the economic conditions. On the opposite side, cluster 3 suggests a situation where a limited portion of the population is exposed to floods, the amount of suffered damages was low as well, whereas the increase in income was rather significant. Compared to each other, cluster 1 might be associated to a level of low resilience (LR), while cluster 3 to a level of high resilience (HR). In the middle, cluster 2 exhibits a limited portion of exposed population and of suffered damages, though the economic welfare is not particularly encouraging. Consequently, cluster 2 might be related to a medium level of resilience (MR) (Fig. 7.8).

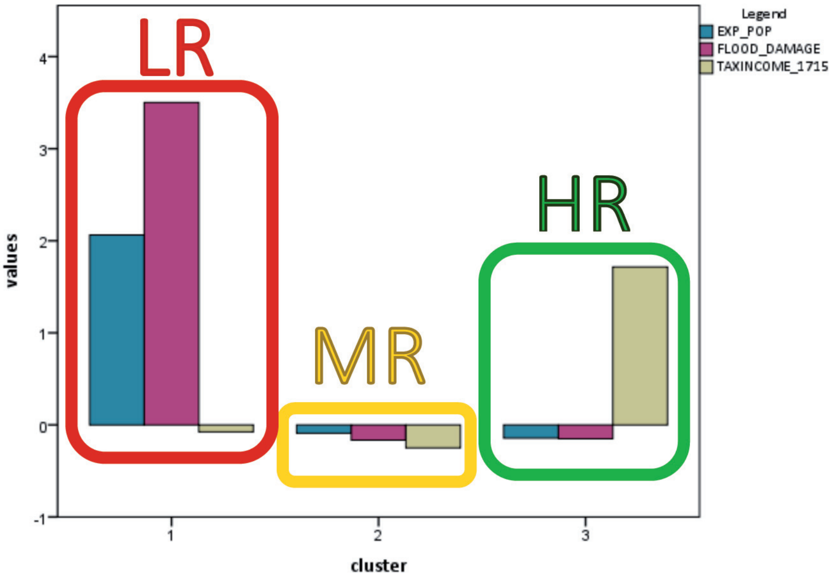


Fig. 7.8 - Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) of resilience (R)

It appears that a significantly limited share of the municipalities (8 out of 179) exhibits concerning conditions in terms of resilient capacities, whereas most of the local communities (149 out of 179) shares relatively intermediate features, and some (22 out of 179) achieves the most desirable status (Tab. 7.4).

Tab. 7.4 - Distribution of the municipalities of Hokkaidō between the clusters and the levels (high H, medium M, low L) of resilience (R)

Cluster	*Level of resilience*	*Number of municipalities*
1	LR	8 (4.47%)
2	MR	149 (83.24%)
3	HR	22 (12.29%)

Overall, the municipalities of Hokkaidō appear rather homogenous in terms of disaster behaviour, exhibiting a similar performance that aggregates them (83.24%) in a comparatively balanced condition of neither *attribute* being fostered more than the others, though neither being particularly developed. Consequently, in relative terms, Hokkaidō does not appear to lie in alarming conditions, although some improvements might be encouraged. Nevertheless, the limited share of municipalities (4.47%) that exhibits a low coping capacity should represent a priority to enhance the overall resilience of the prefecture. Thence, it might be interesting to identify the areas of the prefecture where the most significant critical issues lie (Fig. 7.9). Also in this case, it is significant to remind that these considerations are valid in comparative terms, meaning that the attribution of the resilience levels represents the relative behaviour of a municipality compared to that of the other municipalities of Hokkaidō.

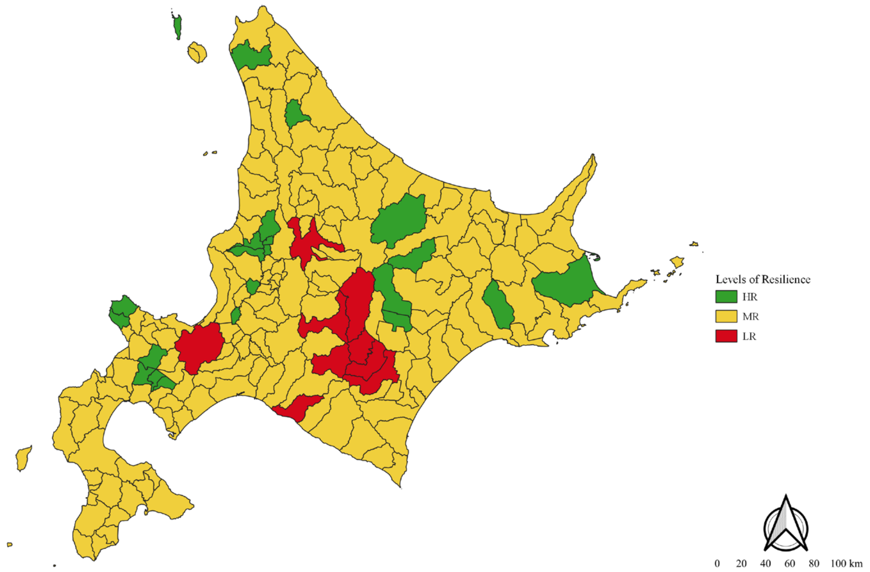


Fig. 7.9 - Distribution of the levels (high H, medium M, low L) of resilience (R) among the municipalities of Hokkaidō

As previously mentioned, the distribution of the levels of resilience appears rather consistent throughout the prefecture. The municipalities that were associated with the most performing behaviour seem to be scattered over the region or in some case aggregated in groups of 2 to 5 components. On the contrary, the more critical *units* seemed to be limited to some specific areas, forming a main group in the central part of the prefecture, with three satellite *units*. Such agglomerative behaviour might suggest that some specific local features might play a decisive role (Fig. 7.10).

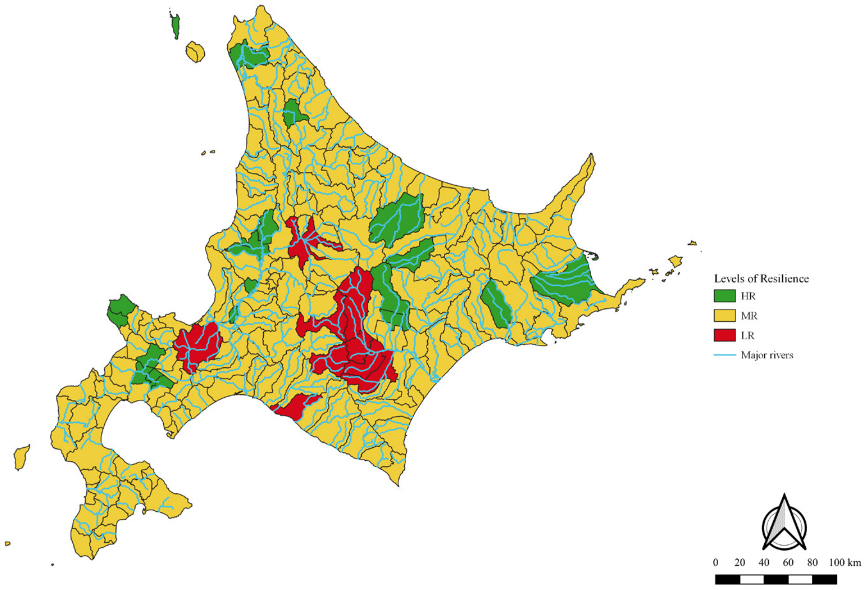


Fig. 7.10 - Distribution of the levels (high H, medium M, low L) of resilience (R) and of the rivers of Hokkaidō

Indeed, the cluster of municipalities that exhibit the most critical resilience capacities lie in the upstream area of the Tokachi river, whereas two of the satellite *unites* (among which Sapporo-shi) stand alongside the Ishikari river, respectively in the extreme upstream and downstream of the river. This observation and the weight held by the indicator related to flood damages suggest that the characteristics of these rivers, and especially of the Tokachi river, might have played a significant role in influencing the resilience of those communities. Indeed, the municipalities that reported the widest amount of damages after the flooding event seemingly correspond to those grouped together upstream of the Tokachi river. In particular, the absolute amount of damages reached an order of magnitude higher than the second most affected group. This correspondence suggests that the Tokachi river basin, especially the innermost part, might be especially susceptible to suffer from extreme events, as indeed appears to have happened in 2016. Consequently, the Tokachi river basin might particularly benefit from dedicated efforts to strengthen the local capabilities to cope with a flood event. In more general terms, the magnitude of consequences endured after the 2016 event was pivotal in separating the municipalities into two main behavioural groups, isolating those that were most vulnerable. Nevertheless, Sapporo-shi fall outside these boundaries, since the reported damages were not particularly high. In this case, the hampering factor of the local flood resilience might have been the rate of population exposed to flood hazard, as this municipality exhibits indeed the highest absolute value. This outcome confirms the relevant role played by a comprehensive planning and management of human landscapes in preventing disasters from occurring and impacting on local communities. This might also turn especially significant when large settlements are involved, as such places draw a consistent flux of people, different for personal capacities and vulnerabilities, that tailored management strategies should be able to address.

7.2.1.2. Sustainability

The metrics of the selected combination exhibited a rather consistent performance, as few iterations were necessary to confirm and stabilise the initial position of the centroids (Tab. 6.27, Tab. 6.28 and Tab. 6.29). Consequently, also in this case the distribution of the municipalities between the clusters might be assumed as reliable, since the differences among the groupings were evident since the beginning. All the indicators were statistically significant and were associated to comparable weights, although the indicator related to the distribution of alien species resulted slightly more powerful than the others in separating the clusters (Tab. 6.30). Along with the stability of the centroids, such consistency of the differentiating potential might suggest that the implemented metrics were all pivotal in terms of environmental sustainability. Nevertheless, it might be interesting to note that even with a limited advantage, the first indicator for relevance concerned the presence of the raccoon (浣熊, *araiguma*). In other words, the most influencing factor was the direct impact on natural equilibria of human fashions. Indeed, the introduction of the raccoon in Hokkaidō followed a trend prompted by a beloved movie and the later realisation of the non-domestic attitude of such animals, thus released in the wild, hampering the stability of the local habitats.

In general terms, this outcome reasonably suggests that the wider an area is colonised by an alien species that competes with the local ones, and the lower the inherent wellbeing of the local ecosystem, thence the lower the sustainability of the local human community. Furthermore, the more extensively the vegetation is negatively affected, and the less the ecosystems are able to deliver their services. Consequently, this trend might be translated into a lower level of sustainability of the human system that has induced such an alteration. Lastly, the presence of infrastructures related to the power supply system might be considered as a negative impact, thus contributing to lower the overall level of sustainability, given the inevitable modification of local features in order to transform natural dynamics into energy for anthropic purposes. These criteria might be applied to the bar graph (Fig. 6.4), in order to identify the levels of sustainability between the clusters.

In this case, cluster 1 represents a situation where the amount of altered vegetation is comparably extensive as well as the presence of the *araiguma* in the area, although the number of establishments related to the power supply system is lower. On the other side, cluster 3 suggests a significant alteration of the local vegetation and presence of power supply establishments, whereas the *araiguma* has a limited spread over the area. Eventually, cluster 2 embodies the most consistent conditions, as the altered vegetation, the presence of power supply establishments and of *araiguma* specimens show a descending trend. While cluster 3 might be the most immediate to be associated with a corresponding high level of sustainability (HS), as it embodies the most desirable conditions of a limited anthropic impact on natural ecosystems, the other two cases remain more questionable. Here, the weight associated to the indicators might be effective. Indeed, the differentiating power of the *araiguma*-related metric appeared more solid than that of the power supply establishments (Tab. 6.30). Consequently, the low level of sustainability (LS) might be associated to cluster 1, while the medium level (MS) might be assigned to cluster 3 (Fig. 7.11).

In light of this interpretation, it appears that a high share of the municipalities has a rather sound relation with the natural environment of Hokkaidō (119 out of 179), while the remaining municipalities are almost equally distributed between a balanced (32 out of 179 municipalities) and a critical (28 out of 179) condition (Tab. 7.5).

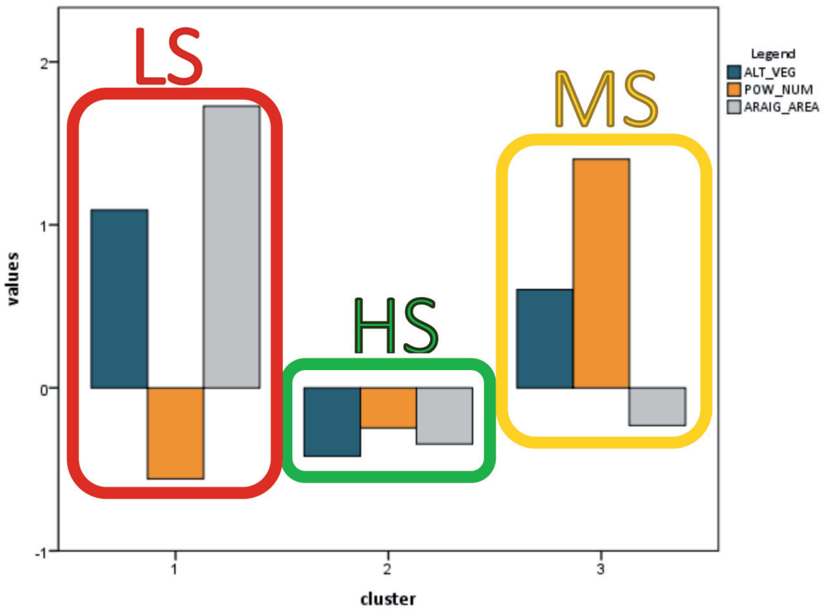


Fig. 7.11 - Bar graph of the centroids per each cluster and each indicator, in terms of levels (high H, medium M, low L) sustainability (S)

Tab. 7.5 - Distribution of the municipalities of Hokkaidō between the clusters and the levels (high H, medium M, low L) sustainability (S)

Cluster	*Level of resilience*	*Number of municipalities*
1	LS	28 (15.64%)
2	HS	119 (66.48%)
3	MS	32 (17.88%)

The overall environmental sustainability of Hokkaidō seems quite consolidated, as the wide majority of the municipalities achieved the most desirable conditions (66.48%) and only a limited fraction exhibits a more concerning status (15.64%). Although such classification remains valid only in relative terms, it might still be interesting to identify which areas of Hokkaidō present the most significant challenges in terms of interactions with the natural ecosystems (Fig. 7.12).

Observing the distribution of the levels of sustainability throughout the prefecture, it appears that a central, vertical band gathers the lowest levels and expands towards the eastern side through the (majority of the) medium levels. In other words, it seems almost as if these municipalities were connected through a pattern that involves the central part of the

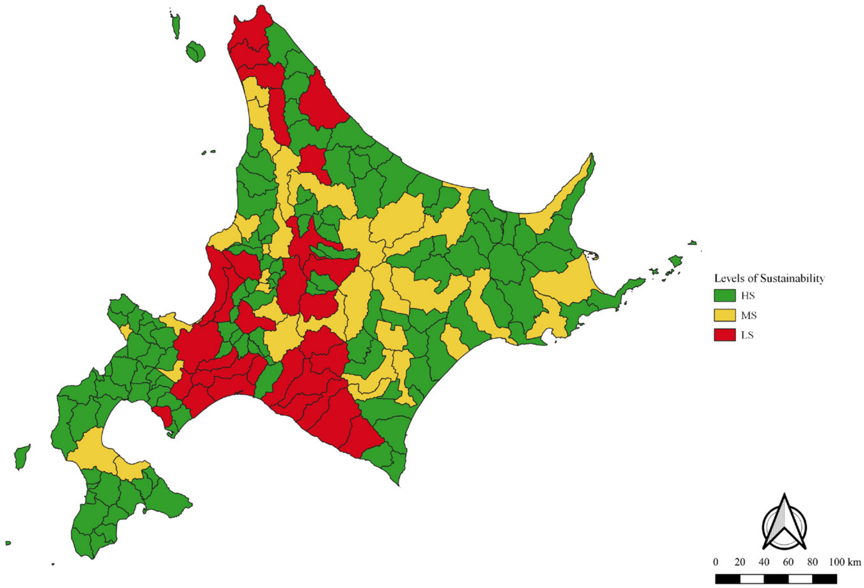


Fig. 7.12 - Distribution of the levels (high H, medium M, low L) and sustainability (S) among the municipalities of Hokkaidō

island, further extending northwards and eastwards. Consequently, it might be relevant to investigate the possible underlying causes of such a common behaviour, that might be identified in either topographical or social features (Fig. 7.13).

It is possible to tentatively identify a major catalysing factor of the most critical performances, being the presence of some of the most important municipalities of the prefecture. Indeed, most of the lowest levels are associated to the area surrounding Sapporo-shi and extending towards Chitose-shi and Tomakomai-shi, whereas a second visible cluster revolves around Asahikawa-shi. In these cases, the topographical and the social features might result simultaneously significant, as the presence of a fluvial plain typically corresponds to a concentration of people, infrastructures and assets. Notably, both these clusters concern the Ishikari river system, although involving the final and the initial section of the river basin, respectively. Nevertheless, the Chitose-shi and Tomakomai-shi section are not related to the Ishikari river, though, the absence of significant natural barriers, such as high mountains, might have reinforced the effect of the social factor in terms of population distribution and thence of related pressure on the environment. In addition, among the 10 most populated

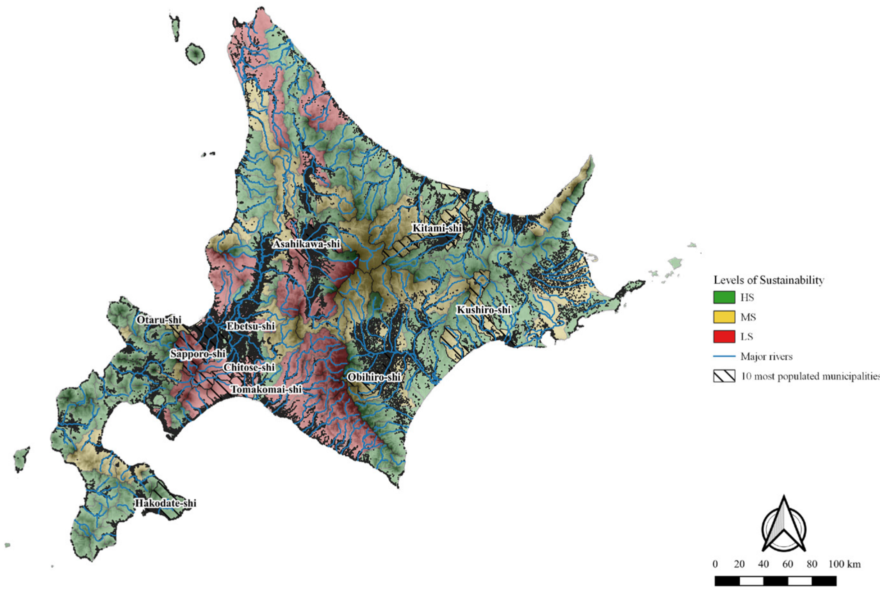


Fig. 7.13 - Distribution of the levels (high H, medium M, low L) of sustainability (S) and morphological features among the municipalities of Hokkaidō

municipalities, the absolute majority shows medium to low levels of sustainability. This possibly implies that the resources available to larger administrative units to improve their coexistence with the surrounding environment might not be sufficient to compensate the impacts caused by such settlements. In particular, coming back to the metrics that led to such classification, it might be interesting to investigate what determined the allocation to the different levels of the 10 most populated municipalities. It emerges that, especially concerning the extremes, they do not exhibit an evidently polarised behaviour, but rather the picture is blurred, and the prevalence of a feature determined the association to a specific level. In other words, for instance, the association to the lowest level was not determined by a common trend towards the least desirable values of the employed indicators, but rather by a significantly low performance in a specific domain. The case of Sapporo-shi is indicative in this sense, as the number of establishments referring to the power supply system appeared unaltered and the effects of the vegetation are significant, although extremely high; the wide spread of the *araiguma* raccoon reasonably forced the municipality in the cluster of the low level of sustainability. In this case, a fundamental turning point might be a sounder awareness of the impacts of human activities on the equilibria of natural ecosystems and on human communities as well in the long term, thus preventing further inappropriate behaviours. Similarly, the belonging to the highest level of sustainability was not determined by a general convergence towards the most desirable values of the adopted indicators, but rather by a particularly encouraging performance in a domain that compensates for a less desirable condition in another domain. In these cases, the indicators of altered vegetation and *araiguma* raccoon distribution played the most significant role.

The above observations are valid for the two mentioned main clusters, revolving around municipalities that exhibited a strong relation between their social and topographical features and the lower levels of sustainability. However, two additional groups of municipalities associated to low levels of sustainability need further investigation, one lying in the northern side of the island and the other in the central-south area. These cases are physically separated from the other dominant groups, pertain to different river basins and do not show a particularly high presence of population. Here, the number of power supply establishments was overall similar among all the municipalities and to the values of the other clusters of low sustainability. The other indicators (altered vegetation and distribution of the *araiguma* raccoon) varied more evidently, although the values always tended to the least desirable end, especially for one of the metrics when the other was less concerning. In other words, these two additional clusters of low sustainability were characterised by a generalised trend towards a significant impact on the natural ecosystems. This consideration appears especially interesting when these areas do not show a particularly significant human presence. As a consequence, it might be suggested that such impacts might be caused to the intense effects of a limited community. If that was the case, in these areas the enhancement of strategies to raise environmental awareness and the endorsement of an attentive management of natural resources might be especially beneficial to improve the local relation with the local ecosystems.

7.2.2. *Second phase – characterisation*

7.2.2.1. Resilience

The second phase started with the selection of an additional set of indicators describing the characteristics of the municipalities. Given the statistical consistency of the selected combination, this case was particularly interesting because of the rather high discriminant potential that could be estimated (Tab. 6.33 and Tab. 6.34). Indeed, the combination appeared able to explain about the 81.4% of the variation among the clusters. This results especially encouraging in terms of reliability of the discriminant function and on the suitability of the chosen indicators. In addition, when testing the actual accuracy of its predictive potential, the discriminant function delivered a noteworthy outcome. Indeed, though limited by a severe lack of information concerning one indicator, the function was able to assign always the same cluster that was identified by the previous cluster analysis to the municipalities. Thence, this appears as a validation of the reliability of the combination. Consequently, it might turn especially informative to investigate which indicators contributed the most to such a discriminating potential. Also in this case, a rather peculiar outcome emerged, as some indicators appeared to particularly influence the overall differentiating potential of the function. Such indicators were the investment in social welfare and the presence of doctors in medical facilities, followed only at a sensible distance by the funds provided to the firefighting corps. In brief, the differences in disaster behaviour of the municipalities seemingly depended mostly on the extension and reliability of the social and health care network. In general terms, the presence of an extensive welfare system might reveal an attentive care devoted to the most fragile persons, and thence it might demonstrate a proactive approach to the reduction of vulnerability. This approach might be complemented by a solid first-response system, exemplified by the public support to the firefighting corps. In a more general perspective, reducing susceptibility while enhancing an effective emergency response might reasonably represent an efficient strategy to strengthen resilience capacities. Lastly, it might be interesting to observe how the demographic features (e.g. age, gender, immigrants), that are usually assumed as the main factors influencing the resilience of a community, did not particularly contribute to the discrimination among the different levels of resilience, in this case. This might be due to the overall homogeneity of the municipalities, which blurred the picture. In this case, a "traditional" assessment of resilience might have delivered a homogeneous outcome as well, whereas the introduction of indicators referring to a wider range of domains as well as the analytical identification of the relative weights seemed beneficial for the emergence of the specific features of the locales, in terms of both strengths and weaknesses.

7.2.2.2. Sustainability

In this case, the canonical correlation resulted the especially high, although it was not particularly relevant in terms of differentiating potential (about 35.3%) (Tab. 6.36 and Tab. 6.37). This might suggest that here the process might benefit from a broadened set of indicators, in particular including metrics referred to a wider range of domains. Indeed, the limited number of indicators that could be included due to limited data availability might have significantly hampered the process. Nevertheless, when comparing the clusters predicted by the discriminant function to those assigned by the cluster analysis, it was possible to observe a valuable outcome, as the wide majority of the municipalities (70%) were associated to the same level of sustainability. Consequently, it appears that the above-mentioned improved combination of indicators might optimise the accuracy of the discriminant function, although the performance is already rather appreciable.

In any case, it might be interesting to investigate which features were the most effective in drawing the differences among the municipalities. Here, the role of the vegetation appears pivotal, in terms of both woods and grassland, both natural and farmed. Notably, the overall performance of the function increased especially when forests and grasslands were considered as separated metrics. The fact that the highest discriminating power was held by this kind of indicators might be especially significant for Hokkaidō, a prefecture renowned for its natural landscapes and relying on agricultural activities. Under these premises, the alterations induced to the natural environment mark more than other features a substantially different approach of a community towards the ecosystems. That is, in a setting generally characterised by a sort of symbiosis between human activities and natural ecosystems, a deviation from this general trend represents an evident conflict. In this sense, monitoring the sustainable development of local communities might be especially relevant for the social-ecological system of Hokkaidō, where the interdependence of the human and natural components is so evident. Nevertheless, in this case it would be especially significant to enhance the accuracy and reliability of the predictive function. In particular, the application of this tool was critically hampered by some missing information that prevented the function to be employed. Consequently, along with the inclusion of a wider set of indicators, it might be relevant to enhance the available information of those already selected, or in turn replace them with others owning a similar meaning and a more complete dataset.

7.2.3. *Insights on local panarchy conditions*

Once the assessment procedure was completed for both resilience and sustainability cores, the municipalities of Hokkaidō resulted associated to the related levels. At this point, it was possible to assess each combined level of disaster resilience and environmental sustainability (Tab. 7.6). Later, it is possible to visualise once more the municipalities, representing their status in terms of position in the respective adaptive cycle, thence portraying the status of Hokkaidō through the semantics of the panarchy metaphor (Fig. 7.14).

Tab. 7.6 - Municipalities (number and share) per combined level (high H, medium M, low L) of resilience (R) and sustainability (S) and presence in the fore-loop of the adaptive cycle

Number of municipalities	*Combined level of resilience and sustainability*	*Share of the municipalities*
17	HR-HS	9.50%
4	HR-MS	2.23%
100	MR-HS	55.87%
121	*fore-loop*	67.60%
25	MR-MS	13.97%
24	MR-LS	13.41%
3	LR-MR	1.68%
3	LR-LS	1.68%
1	HR-LS	0.56%
2	LR-HS	1.12%

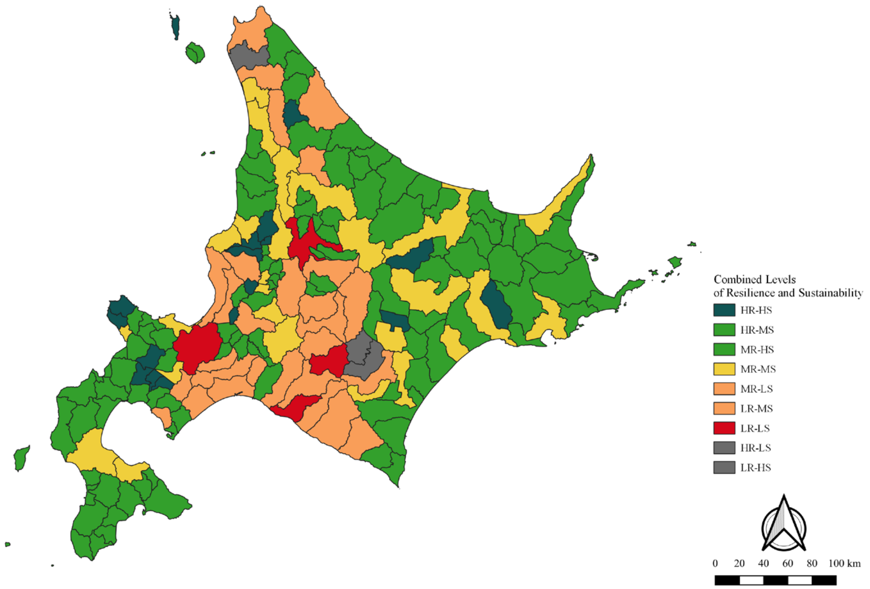


Fig. 7.14 - Distribution of the combined levels (high H, medium M, low L) of resilience (R) and of sustainability (S) among the municipalities of the Hokkaidō

The overall picture of Hokkaidō appears rather varied in terms of combined levels of resilience and sustainability, with all levels represented. Even though this might be especially positive for the most desirable conditions, it also means that the least desirable conditions are present across the prefecture, in terms of both combined lowest levels and *traps*. From a quantitative standpoint, although a limited fraction exhibits the combination of the highest levels (9.50%), the overall situation is rather reassuring, as the majority of the municipalities (67.60%) lies in the *fore-loop*, assumed as the most desirable segment of the *adaptive cycle*. Nevertheless, the presence in the segments surrounding the most unstable and uncertain phase of the *adaptive cycle*, that is the *release phase*, should not be underestimated. Indeed, about 1 every 6 municipalities (16.77%) presents a low level of either resilience or sustainability, apart from those in an extremely unbalanced situation, that account for a very limited fraction of the municipalities (1.68%). In brief, although Hokkaidō mainly implements a successful approach towards disaster and environmental issues, there still appear to be some clusters demonstrating a comparatively less effective approach. Although this investigation does not allow for a generalised comparison among different geographical areas, it may still provide some relevant insights for local policies and management strategies, for instance by mapping the distribution of the levels across the prefecture. The municipalities associated to the highest levels of resilience or sustainability (HR-HS, HR-MS, MR-HS) appear scattered throughout the prefecture, and even if some examples can be found also in the inner land, the majority lies along coastline. On the contrary, the most concerning conditions seem to be mainly aggregated in a central group that includes all the variations in terms of low and medium levels and revolves around the municipalities associated to the most critical level (LR-LS). Therefore, it appears that the inner areas would be those benefitting the most from focused management and support. In this case, it would be relevant to identify the reasons for such an unfavourable outcome. The investigation on disaster behaviour was dominated by two different themes: flood damages and population exposure. Although concerning different domains of the *resilience core*, both metrics address a common, fundamental feature of human communities, that is their susceptibility. In other words, the emerging importance of these themes appears to confirm that a significant driver of disasters lies within human attitudes. Consequently, strategies fostering adaptation approaches as well as focusing on raising awareness might effectively increase the resilient capacities of local communities, thus reducing the destabilising impacts of an extreme event. From the sustainability side, the overall picture is even more homogeneous. The lowest level was mainly due to the extension of *araiguma* distribution, though also the alteration of the vegetation played a significant role. Nevertheless, the presence of alien specimens (that were artificially released) is evidence of the profound consequences of human irresponsible behaviour. As such, also in this case raising awareness on the environmental costs of personal habits might be especially beneficial to improve the overall sustainability, particularly in the long term. Nevertheless, it might be relevant to examine more in depth the municipalities lying in the *fore-loop* of their *adaptive cycle*. Their scattered distribution throughout the prefecture might be noteworthy, as it appears to suggest that such a desirable condition should reasonably disregard geographical features, rather concerning more inherent traits. Here, the second phase of the assessment procedure might result particularly informative. The outcomes suggest that local resilient and sustainability capacities would particularly benefit from efforts devoted to developing a widespread network of social welfare infrastructures and to promoting a sound preservation strategy of local vegetation. Indeed, a higher attention to the most vulnerable components of a community might result in an overall mitigation of the susceptibility, also in the long-term. At the same time, furthering the preservation of natural equilibria, especially through the preservation of local habitats and the promotion of lower-impact activities (favouring agriculture rather than heavy industries, for instance), might significantly increase the wellbeing of the local ecosystems, thus stabilising the services that are vital for human communities.

8. Partial conclusions

The *objective* of the present discussion was to explore the interactions among the human and the natural components of a social-ecological system, and in particular the conditions that support an overall long-term survivability of the system. In order to pursue such aim, first, a theoretical framework was defined to model the inherent dynamics, and then, a methodology was developed to quantitatively assess the specific conditions.

The first part of this research adopted the panarchy model, further adapted to the domain of disaster risk reduction. This allowed to outline the **Social-Ecological Panarchy model**, that aims at visualising the possible interactions among the components of a social-ecological system and in particular the critical features that might enhance or jeopardise the long-term survivability of the system. Then, it was possible to design a quantitative methodology, useful to identify the levels and conditions of resilience and of sustainability of a specific social-ecological system. That is the **Combined Assessment of Resilience and Sustainability (CAReS) methodology**.

In the second part of the research, such framework was applied to two case studies, the Marche region (Italy) and Hokkaidō (Japan), considering a flood risk scenario, at a municipal scale of analysis. The application of the proposed methodology to these case studies allowed to investigate their specific features in terms of levels of resilience and of sustainability. The case of the Marche region exhibits an overall prevalence of the most desirable conditions, of both resilience and sustainability, whereas the least favourable conditions are showed by a limited portion of municipalities. The case of Hokkaidō was rather different, as the majority of the municipalities showed a medium degree of resilience capacities, while their sustainability appeared generally more robust. Although the assessment methodology does not allow for a direct comparison of the outcomes, some overarching insights might still be drawn. For instance, it might be noteworthy how for both Marche region and Hokkaidō, and for both resilience and sustainability, the most critical issues appear localised in the mountainous and hill areas, while the coastlines exhibit a sounder general status. Furthermore, such issues seem often clustered in small groups, including up to ten municipalities. These common traits suggest a general inherent fragility of the inner areas, fragility often not related to the specific characteristics of a municipality, but rather associated to those of a surrounding narrow area, exceeding administrative boundaries. Consequently, it appears that such areas would especially benefit from a tailored strategy to enhance the local sustainability and resilience capacities. In this regard, some significant understandings might come from observing the behaviour of municipalities under critical conditions, identifying the traits especially relevant to the least desirable performances. In terms of resilience, damages suffered by the local communities during a flood event appear to play a common dominant role. Furthermore, the variation of the income of local communities appears significant for the Marche region, whereas the population exposure to floods appears more significant for Hokkaidō. Hence, as a general criterion, the improvement and adaptation of the anthropic features to the local natural dynamics appears pivotal to influence disaster behaviour. From a sustainability perspective, the picture was more multifaceted, although also in this case a common trait arose, that is the direct alterations caused to the natural ecosystems by anthropic activities. Even though differently represented, this feature suggests that the approach towards the surrounding natural landscape significantly affects the sustainability of a municipality. Accordingly, the promotion of the preservation of the natural features of an area appears to hold a general, pivotal weight in terms of sustainable behaviour.

While these considerations are related to the specific behaviour of a municipality in case of an extreme event, it was deemed relevant to identify the general characteristics that led to that behaviour, hence the second part of the analysis focused on the features that typified the case studies. Although also in this case the outcomes are not directly comparable, it is still possible to draw some general insights. In terms of resilience, the characterisation resulted rather different between the two case studies. Indeed, while for the Marche region the demographic variables emerged as the most relevant, followed by the presence of volunteers, for Hokkaidō the network of the welfare system resulted the most important feature. Consequently, the structure of the emergency response system appears a common fundamental asset, in one case represented by the population devoted to the social welfare and protection, in the other case by the support to social and firefighters' duties and the presence of doctors. This is in partial contrast with the indicators commonly adopted to assess the resilience of a community. Indeed, often priority is given to demographic and economic variables (for instance female population, level of education, income), whereas the outcomes of this research suggest that even though they certainly contribute to outlining the resilience capacities, they might not be the most significant factor for every case study. Hence, while it is important to include them in an assessment due to the implied meaning related to expected attitudes, it seems that this kind of indicators might not be sufficient, and they should be combined with indicators on the disaster-response capacities, at least. Notably, this outcome suggests also which domains should favoured in order to increase the overall resilience of the community, being the welfare system and emergency response system. When turning to the sustainability capacities of a community, the presence and extension of vegetation, both natural (forest land) and semi-natural (agricultural land), emerged as a common, important element, along with the protection and conservation of natural environments. Indeed, the preservation of natural habitats is pivotal for the survivability of ecosystems, as they provide the setting for species to prosper, sustaining the biodiversity of an area, thus fostering the provision of ecosystem services and functions. Similarly, not only an agricultural setting might constitute a specific habitat per se (e.g. paddy fields), but it might also deliver specific ecosystem services (for instance, air or water quality maintenance), thus contributing to the stability of the local natural environment.

At this point, it was possible to re-compose the complex picture, by combining the evaluations of resilience and sustainability. Hence, it was also possible to assess the position of each municipality within their *adaptive cycle*. The distribution of the combined levels of resilience was rather varied throughout the case studies, though the inner areas suggested more urgent issues to be addressed, compared to other parts of the regions. Indeed, the majority of the municipalities lying in the most critical segments of their *adaptive cycles* appeared located in the mountainous and hill areas of the Marche region as well as of Hokkaidō. It appears that in both cases those would be the areas benefitting the most from targeted strategies and actions to enhance a sounder interaction with the natural environment. Furthermore, the presence of municipalities trapped in unbalanced conditions should not be underestimated. That is, *traps* represent an undesirable status, as the prominence of either resilience or sustainability over the other translates in uneven conditions that could hamper the overall development in the long-term. Despite such critical issues, both case studies exhibited an overall encouraging condition, as the majority of the municipalities lied in most desirable segment of the *adaptive cycle*, that is the *fore-loop*. Although a comparable portion of municipalities presented such status, the Marche region showed more balance between resilience and sustainability, with a slight preference over sustainability, whereas Hokkaidō appeared to favour sustainability to resilience more markedly. Within the panarchy metaphor, apparently both case studies reside in the *fore-loop* with a tendency to shift towards the *conservation phase*. While this indeed is a desirable condition, as it denotes a successful human-nature interaction, it might also suggest that endeavours should be directed towards the enhancement of strategies to strengthen the resilience capacities of the local communities, in order to move the municipalities towards the centre of the *fore-loop* of their *adaptive cycles*. In both cases, indeed, while the most severe issues are more spread in terms of sustainability (that is, the low level of sustainability is more common compared to the low level of resilience), the best performances in terms of resilience are less spread compared to sustainability (that is, the high level of resilience is less common compared to the high level of sustainability). Hence, both cases suggest that, though serious environmental issues exist and need to be addressed, a broader effort should be devoted to increasing the capacity to effectively cope with disasters. In brief, environmental issues emerge as local urgencies, whereas disaster risk reduction seems to require a more thorough approach. This kind of understandings is intended to inform the design of policy instruments. Evidencing the different temporal perspectives and urgency of the emerged issues might result beneficial to identify the most appropriate solution. For instance, environmental problems might require tailored and rapid resolutions, whereas disaster resilience might find a higher benefit from a pervasive activity throughout the area.

At this point, the quantitative assessment comes to a conclusion, though a further issue arises. Indeed, it might be questioned whether such a representation is valid and captures all the relevant features of the municipalities. While statistical tests provide a verification that address the methodological validity of the procedure, its conceptual validity needs further considerations. In order to address these issues, the following paragraphs will introduce the perspective of local populations, investigated by means of qualitative techniques.

PART III – Qualitative assessment

9. Literature review

The previous discussion explored and applied a quantitative methodology to assess the resilience and sustainability of a community. Nevertheless, a community displays not only quantifiable features, but also traits and attitudes deriving from the interaction of the population with the surrounding landscape. Hence, it might be relevant to investigate how the locals conceive the *resilience* and *sustainability cores* of their community.

The engagement of local populations in the management activities of their communities is a relatively recent phenomenon, although the call to involve locals and to exploit local knowledge is gaining a wide echo (Bodoque et al., 2016). For instance, the Sendai Framework for Disaster Risk Reduction explicitly advocates the inclusion of local stakeholders and more vulnerable groups in the planning of effective strategies and in their successful implementation, considered as a crucial progress towards building more resilient communities (UNDRR, 2015). In general, local populations appear to play a pivotal role in the outcome of the strategies concerning disaster resilience as well as environmental sustainability. Indeed, exploring the willingness to adopt protective measures or to support risk reduction plans could turn crucial to boost the efficacy of enacted policies (Kellens et al., 2011). Similarly, the perception of environmental issues could be critical to design proper communication and educational strategies, as well as to consolidate the public acknowledgement of local policies (Vincenzi et al., 2018). The quantitative approaches that have been widely employed to assess resilience and sustainability might not be able to comprehend all the facets of such a complex picture. Research efforts are indeed shifting towards more integrated approaches, some that encompass more qualitative measures (Forino, 2012; Kellens et al., 2013; Reed et al., 2005; Santoro et al., 2019), investigating the local perception of resilience and of sustainability, pivotal to foster both *cores* (Hawkes

& Rowe, 2008; Vincenzi et al., 2018). In light of these observations, the proposed methodology should be further integrated with qualitative analyses, while still relating to the overall theoretical framework (that is the Social-Ecological Panarchy model).

In general terms, a "perception" deals with the representation of a surrounding reality as it is processed through the senses. Consequently, the matter of perception is inherently subjective. A manifold of variables influences this issue, stemming from personal, to social and environmental characteristics. When it comes to the perception of more specific themes, such as disaster risk and environmental sustainability, the level of complexity cannot but amplify. Even though risk perception and environmental perception concern different domains, hence they have been examined from different perspectives, some common features have emerged. In particular, risk or environmental perception is not a mere consequence of physical characteristics and objective events. Rather, it is affected by attitudes, behaviours, expectations, constructs developed both at an individual and at a societal level (Sjöberg, 2000; Vincenzi et al., 2018). An exemplification can be identified in the discussion relating to risk perception. While risk might be assumed as the probability of the occurrence of a certain hazard, hence it can be referred to some objective variables, risk perception is influenced also by the sense of security provided by the overall community to the individual, thus a function of personal attitudes and priorities, social cohesion and external pressures (Boholm, 1998). Consequently, a phenomenon might be decoded in completely different ways depending on the population involved, and an objective metric might assume different meanings depending on the population addressed (Boholm, 1998). A further example is provided by the seminal work of Slovic (1987): "*The concept of "risk" means different things to different people*" (p. 283). The author showed as such a difference becomes radical when the judgements of experts and laypeople are compared. While experts mainly rely on measurable indicators of harm to victims, laypeople might still provide an objective quantification of risk (such as estimates of mortality rate), but their judgement is richer in variables, such as the consequences for future generations or the potential of catastrophes. More in general, among the various aspects that influence risk perception, some seem to be more relevant, like the familiarity with the hazard typology and dynamics (e.g. train wreck vs. nuclear power), and the severity of the consequences (extension of the caused harm). Nonetheless, such a discrepancy in judgement might not always be substantial. For instance, when asked to rank a series of environmental risks, experts and laypeople delivered consistent evaluations of the risks connected to global environmental changes (e.g. species loss, climate change), positioning them in the levels with higher potential impacts (McDaniels et al., 1996).

Despite such complex issues, research efforts have flourished, based on the assumption that perception and attitudes can indeed be measured (Boholm, 1998; Sjöberg, 2000). The discussion surrounding risk perception opened in the 1940s by White (1945), who exposed the influence of past experience of flood on the behaviour under the threat of a future flood (Kellens et al., 2013). A further pioneering contribution was provided by Starr, who quantitatively estimated the correlations between public acceptability of risk and a manifold of variables (e.g. voluntariness of risk, related benefits) and exposed the potential informative value for risk management (Starr, 1969). Stemming from these seminal works, two major approaches have been developed: a psychometric approach, rooting in the positivist tradition, and a cultural theory approach, relying on the concept of risk as a societal construct (Liu et al., 2018), although the psychometric approach itself appears to be well rooted in the risk perception tradition (Kellens et al., 2013). Notably, there is not a common agreed methodology; questions and approaches are not universally established, but rather adjusted to each case study (Kellens et al., 2013; Liu et al., 2018). This might be possibly due to the explorative stage where this line of research lies (Kellens et al., 2013). In this crucial phase, it is pivotal to investigate which relevant variables need to be included. For instance, socio-demographic variables proved to hold a crucial role in shaping risk perception (e.g. Liu et al., 2018) and their inclusion has been strongly advised, though some studies overlooked their relevance (Kellens et al., 2011). At the same time, other studies observed a limited influence of those characteristics, in favour of more general aspects, such as social, cognitive and practical motivations (Roder et al., 2019).

In a similar vein, the question of sustainability perception remains open to discussion. The general concern over environmental issues has been growing in the last decades, thus it would be especially relevant to estimate the potential response elicited in local populations (Andries et al., 2012). Nonetheless, the development of an assessment methodology appears not settled, despite several fields already investigated: environmental policy, food, tourism, consumption habits (Vincenzi et al., 2018). In the same way, the outcomes are not unanimous, as for instance university students were found to be rather aware of the growing threats and of the crucial role played by sustainable development for a long-term survivability (Andries et al., 2012), while laypeople appeared to hold a general low sustainability perception (Vincenzi et al., 2018). Moreover, in some cases socio-demographic dimensions exhibited a significant relation with sustainability perception (e.g. Andries et al., 2012), whereas in other cases further variables appeared determinant. For instance, in highly polluted riverine areas, the experience of views and smells coming from the river crucially influenced the local perception (Guida Johnson et al., 2015). At the same time, the vicinity and the tighter relation to the riverine area appeared fundamental, to the point that the higher awareness expressed by women faded with the increasing distance from the water body, thus limiting the influence of commonly employed demographic variables (Guida Johnson et al., 2015). Indeed, when that kind of spatial variation was specifically explored, cluster of different environmental perception emerged evidently, in spite of socio-economic features of the addressed community (Brody et al., 2005).

Stemming from this brief exploration, it appears confirmed that where qualitative approaches broaden the picture, quantitative approaches extrapolate the dominant lines. Consequently, quali-quantitative techniques (i.e. questionnaires) result a particularly effective strategy. As mentioned, there is not an overall agreement either on the variables to include in the investigation or on the questions to deliver, although the psychometric paradigm appears to be widely adopted. This approach employs questionnaires in order to collect the perceptions of the respondents through preferences expressed on rating scales and concerning several features of the investigated problem (Benthin et al., 1993; Kellens et al., 2013). A particularly common scale is the Likert, and Likert-type, scale (Boylan & Lawrence, 2020). The Likert scale was introduced in the 1930s with the specific aim to investigate people's attitudes (Likert, 1932). This technique provides a single statement and solicits the expression of a preference in terms of gradation of accordance, usually identified through a sequence of integer numbers, with stages horizontally arranged, evenly separated and with verbal labels symmetric to a neutral middle (Uebersax, 2006). Some variations are not uncommon, especially in the structure (including the visual appearance) and in the type of verbs employed to collect the rate of agreement, thus the classification of Likert-type scales (Guerra et al., 2016). Although it is fundamental to provide enough grading options to include the respondent's perception, it is advised not to exceed in width, as too many possibilities might result confusing, thus hampering the reliability of the answers (Sjöberg, 2000). Hence, options should be kept between 3 to 7 points (Boylan & Lawrence, 2020; Sjöberg, 2000).

Once the questionnaire is designed, the following step concerns the sampling of the population. The available techniques fall into two main categories: probability or non-probability methods, depending on whether the aim is to target the general trends or to focus on a specific population (Kellens et al., 2013). The use of one or the other might depends also on the context of the research: for instance, flood risk perception appears dominated by questionnaires delivered to probability-sampled respondents, in order to grant the representativeness of the outcome (Kellens et al., 2013), whereas interviews administered through non-probability sampling techniques appear more common among (generic) risk perception studies (Kellens et al., 2011). Concerning risk perception, it also emerges that even though it might be possible to identify complex risk scenarios affecting a selected population, the investigation is often reduced to a single-hazard, thus focusing questions and perspectives (Kellens et al., 2011). In addition, it has been advised not to rely on risk perception in order to estimate the willingness to reduce risk itself, but rather the two issues should be treated as independent from each other and not as a mutual proxy (Sjöberg et al., 2004). Indeed, several studies have shown that a manifold of variables influence risk perception, to the point that risk perception is more related to the probability of unwanted outcomes, whereas the demand for risk mitigation is more related to the perceived severity of hazard impacts, rather than to "risk" as a whole (Sjöberg et al., 2004).

Following the previous brief exploration, it might be relevant to bring such observations in the proposed assessment methodology. The previous discussion confirmed the need to integrate the previous (two-phase) quantitative assessment of resilience and sustainability with a third phase, performing a quali-quantitative investigation on risk and environmental perception. It is noteworthy that the scope is still to investigate the level of resilience and sustainability of a community, but in this case the assessment centres on the perception of local populations. The conceptual paradigm of the Social-Ecological Panarchy still drives the operative development of this phase and a possible interpretation of the outcomes. This common background would allow a tentative comparison between the classification deriving from the quantitative effort and that drawn from this qualitative investigation. Lastly, it might be significant to collect information on some relevant issues concerning the two *cores*, related to the adopted panarchy metaphor: for instance, according to local populations, which are the fundamental functions of the anthropic and of the natural systems? Where is the threshold that marks the boundary of a collapse? Are there any relations among individual or local characteristics and perceived levels of resilience and sustainability?

In light of the above considerations, the following paragraphs will outline the driving questions that will expand the proposed methodology, by means of an exploration of the local perception of resilience and of sustainability.

10. Further assumptions, objective, hypotheses and questions

Local populations live in close relation with their regions. In particular, the development path of local communities inevitably responds to local geographical narratives. Hence, the role of local populations is crucial in fostering a resilient and sustainable development for the overall social-ecological system. Nevertheless, the endeavour to comprehend the standpoint of locals still appears in its exploratory stage.

The primary *objective* of this study is to further the understanding of human-nature interactions and of their consequences on the survivability of the overall social-ecological system. In order to pursue this aim, the panarchy model was adapted to derive the Social-Ecological Panarchy, and thence to support a quantitative investigation of the conditions of resilience and sustainability of local communities. At this point, the Social-Ecological Panarchy might be support the exploration of how communities comprehend their locales.

In light of these considerations, an additional *hypothesis* was formed:

There is a mismatch between measured and perceived level of resilience and sustainability.

In other words, although there should be a constant effort to foster disaster resilience and environmental sustainability strategies, the engagement of local populations in those endeavours is still not a common practice. Rather, efforts are still mainly directed towards the comprehension of risk and environmental perception. Consequently, local populations might not be aware of the development course undertook by their community and might perceive a condition of resilience and of sustainability that is not informed enough to align with an objectively measurable level.

From here, some related *sub-hypotheses* descend:

First, *local populations tend to underestimate the level of resilience and of sustainability.*

The general low involvement of local populations in the management of their territories might result in a limited awareness of the local initiatives aimed at reducing risk and strengthen sustainability.

Second, *higher levels of resilience and of sustainability blur the mismatch between measure and perception.*

When a manifold of activities is enhanced, the engagement of the local population should be promoted as well, or at least a higher visibility should be granted.

Third, *perceived higher levels of resilience and of sustainability correspond to a higher tolerance of disaster-related nuisances.*

When the awareness of local plans and strategies is high, there is also higher trust and tolerance towards possible inconveniences after an extreme event.

In order to test those hypotheses, the investigation intends to refer directly to local populations. Hence, some *research questions* might be helpful to properly expand the research methodology.

First, *is there any difference between the level of resilience as objectively measured and subjectively assessed?*

Given that local populations are in the forefront when an extreme event strikes, it is fundamental that they are aware of the capacities and assets available to cope with such situations. Unjustified confidence might be highly detrimental, but undervaluing the local capabilities might induce a similar undesirable attitude.

Second, *is there any difference between the level of sustainability as objectively measured and subjectively assessed?*

In order to foster a balanced coexistence of local populations with the surrounding environment, it is crucial that they are conscious of the changes altering their landscapes as well as that they are engaged in the efforts to promote a sustainable lifestyle.

Third, *where do local populations draw the thresholds among the most crucial phases of the* adaptive cycle*?*

Given that local populations live and develop their locales, efforts should be invested in adjusting those locales to the needs and expectations of their inhabitants. Hence, it might be interesting to explore which are the functions that are considered fundamental for everyday life, where is set the limit of tolerance for their failure, what is the accepted extension of recovery. Similarly, these same issues might be directed towards the natural environment, wondering what the most valued services are and what the acceptable level of damaged and of loss is.

In addition, although perception is influenced by a manifold of variables, stemming from personal experiences to societal conditions, a significant role might be played by individual peculiarities and especially socio-demographic characteristics. This matter has been debated both in the resilience and in the sustainability discussion, even though a definitive answer has not been found. Hence, a further *hypothesis* might be proposed:

The perceived level of resilience and sustainability is influenced by socio-demographic aspects.

The perspective, experiences and ambitions of a person might be significantly affected by the features that contribute to shape one individuality. Consequently, the approach towards disaster resilience and environmental sustainability might be influenced as well by the personal and societal constructs experienced by that person.

Consequently, it was necessary to include some more *research questions*:

First, *is there any relation among the perceived level of resilience and the overall socio-demographic variables? Is there any relation among the perceived level of sustainability and those variables?*

It might be interesting to capture the eventual dominant attributes that might influence the perception of an individual. If this was possible, then it would also somehow predict the expected behaviour of a local population.

Second, *if there is indeed a relation, are those variables the same that emerge from a quantitative assessment?*

In case that indeed some demographic variables appear to significantly influence the perception of resilience and sustainability, it might be interesting to verify whether the personal characteristics that lead to a specific level of resilience and sustainability are the same characteristics that influence the perception of those levels. If that was the case, it might be possible to inform and adapt local management strategies to the probable conditions of susceptibility or willingness towards specific risk and environmental issues.

As previously mentioned, at this point it is necessary to include the means to address these further emerged questions in the proposed methodology, adapting appropriate quali-quantitative techniques.

11. *Qualitative methodology*

11.1. An enhanced Combined Assessment of Resilience and Sustainability (CAReS+)

As previously suggested, in this case the aim focuses on the local perceptions concerning resilience and sustainability. As the intention is to outline the general attitudes towards such issues, quali-quantitative techniques, such as questionnaires, appeared the most suitable ones. The proposed (CAReS) methodological framework relies on quantitative assessments, thus the outcomes of questionnaires would facilitate a possible comparison between the results of these two methodological approaches.

At this point, it might be beneficial to summarise the main targets. Stemming from the research hypotheses and questions, some major points might be identified:

- Evaluation of the perceived level of resilience and sustainability;
- Identification of the perceived most crucial functions of the social-ecological system;
- Identification of the perceived critical thresholds in the neighbourhood of the collapse;
- Collection of information on the perceived dynamics of the locales;
- Investigation of the role socio-demographic features among the possible relevant variables.

As mentioned, questionnaires appeared to be especially suitable in the present case. Nonetheless, respondents might want to provide some additional information or share personal experiences. Such material would represent especially valuable information, possibly shedding light on specific processes or events. Consequently, those disclosures should be recorded as well, and considered relevant limitedly to the related community.

A further aspect to clarify is the sampling of the population. Although experts and local authorities might be more informed and aware of the events occurring in a community, in this case the interest is on the perception of laypeople. Professionals might be aware of what is happening, but laypeople especially experience those happenings. In this perspective, the sampling method should tend towards the highest representativeness, hence probabilistic techniques should be favoured.

At this point, it was possible to identify the overarching structure of the questionnaire. In particular, 55 questions were designed and grouped in 3 major conceptual sections, addressing the three driving themes:

1. resilience and sustainability perception;
2. critical functions and thresholds;
3. socio-demographic features.

All questions were explicitly referred to a local community, highlighting the exclusion of the dynamics occurring in the wider regional or national territory. In order to maintain consistence with the previous quantitative assessment, the investigation focused on flood events and related management activities. As a general rule, open-ended questions were limited as far as possible, in order to maintain the highest standardisation of the answers. Nonetheless, with the aim of allowing respondents to freely share their thoughts, a final area was left blank to be spontaneously filled in.

In light of these considerations, the overall methodological framework emerged. The discourses carried by the qualitative and quantitative assessments could be integrated in the proposed CAReS+ (enhanced Combined Assessment of Resilience and Sustainability) methodology (Fig. 11.1).

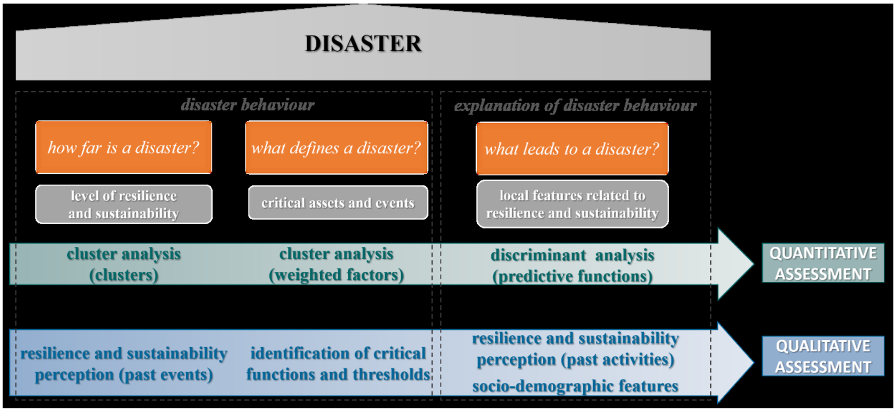


Fig. 11.1 - Structure of the proposed enhanced methodology

It might be especially significant to observe how the quantitative and the qualitative metrics are intended to provide completing information on the response of a community to adverse events and on the features that shape such response. At the same time, both quantitative and qualitative processes provide insights that are valuable as stand-alone outcomes, as the first roots in the consolidated literature, while the latter brings in the voices of locals.

11.1.1. *Structure of the qualitative methodology*

11.1.1.1. Resilience and sustainability perception

The first block of questions (n° 1-29) was dedicated to identifying the level of resilience and of sustainability of a municipality as perceived by the local population. To this end, the questions mirrored the indicators employed in the previous cluster analysis to allow for a direct comparison of the results. Then, further questions concerned other capacities related to the *attributes* (*learn*, *absorb*, *recover*; *services*, *functions*, *integrity*) of the two *cores*: for instance, enhancement of flood management activities (*learn*), typology of assets that would suffer flood damages (*absorb*), return to everyday life (*recover*); use of natural water (*services*), extension of green areas (*functions*), protection of natural areas (*integrity*). In order to associate a level (Low – L, Medium – M, High – H) of resilience (R) and of sustainability (S) to each available option, the answers were designed as Likert and Likert-type scales with three viable preferences. Each answer was assigned a growing numerical value, corresponding to the level: 1 – LR/LS; 2 – MR/MS; 3 – HR/HS. Overall, 1 was related to a "decrease" and 3 to an "increase" in the surveyed variable, 2 was related to unaltered conditions, thence not influenced by flood and flood-related dynamics. This might mean that no changes occurred in the area, or that a variation occurred, but not due to flooding events. Nonetheless, in some cases (questions n° 28-29) four options were envisioned to include a more appropriate range of perspectives on the current situation, although later they were reduced to three levels as well. The correspondence among options and levels was interpreted by the author, following the rationale of considering whether the expressed preference would represent a higher or lower level of resilience and sustainability. For instance, if the respondent declared that the influence of flood risk led to tighter social bonds, this was assumed as a sign of increased resilience (question n° 1). Similarly, if the respondent affirmed an observed worsening of landscape scenery in the past years, this was considered as a sign of decreased sustainability (question n° 25).

Some space was also dedicated to exploring the point of view of the local population on the processes ongoing in their area, as for instance respondents were asked whether they knew some official plans (e.g. Municipal Civil Protection Plan) and how they first came to know them. In these cases, answers were necessarily arranged as multiple choices, although open-ended questions were kept limited, as previously mentioned. In any case, these answers did not contribute to the quantification of the perceived levels, rather providing informative insights.

11.1.1.2. Critical functions and thresholds

The second section (n° 30-37) was designed with the purpose of investigating the most critical *phase* of the *adaptive cycle*, that is surrounding the potential *collapse*. Two questions concerned the identification of the assets considered fundamental for the survivability of the community (n° 30, 34). Then, it was required to express some preferences on the maintenance of such functions in the case of potential heavy damages (n° 31-33, 35-37). Preliminary, it was necessary to select some proxies for those thresholds, able to discriminate among different *phases*. The overarching rationale was based on the concept of "rate of tolerance". For the *resilience core*, it was questioned how long it would be possible to live without critical functions, in case they were interrupted. That is, how long it is possible to tolerate their absence before considering the functions critically lost, thus signalling the collapse (*conservation* to *release phase*). Then the focus shifted towards the recovery time. In particular, the question concerned how much it would be acceptable to wait until the recovery of such functions (*release* to *reorganisation phase*), thus identifying the maximum tolerance of the permanence in the *back-loop*. Eventually, the last question related to the quality of the critical functions after recovery (*release* to *exploitation*), being acceptable as equal or different from the lost ones. For the *sustainability core*, the approach was analogous, except for the first issue, quantifying the acceptable loss of ecosystem services (being equivalent to critical functions). Overall, the questions of this section needed to be a multiple-choice type. When time spans were concerned, different preferences were available for the two *cores*, because dynamics related to human processes were associated to shorter time scales (few hours to one month) compared to the dynamics associated to natural processes (5 years to 20 years).

11.1.1.3. Socio-demographic features

The last section (38-55) of the questionnaire gathered information on the basic features of the population (e.g. age, gender, education), as well as other variables commonly recognised as potential factors influencing resilience and sustainability attitudes (e.g. participation in civic organisations, time of residence in an area). Some of the variables were selected to correspond to those included in the previous discriminant analysis, supporting the comparison between the two methodologies. Here, questions were necessarily multiple-choice and yes/no type. The only open-ended question concerned the related municipality, allowing the respondent to add their own if necessary.

12. The further case study

Once designed, the questionnaire could be administered. Ideally, the questionnaire should be delivered to the case studies that were addressed by the previous phases of the proposed methodology. Unfortunately, resource constraints limited the implementation of this approach, hence it was necessary to narrow down the case study. It is acknowledged here that extending the application of the proposed methodology would significantly improve the overall investigation.

The selection of the suitable case studies followed some overarching principles: *i.* reduce the scale, but increase consistency; *ii.* select a study area affected by flood risk and representative of all the combined levels of resilience and sustainability; *iii.* select 1 *sub-unit* per each combined level of resilience and sustainability, distributed across the study area.

Here, the focus was on the Marche region. In order to reduce the scale of analysis, the river basin was considered the most viable option, also in terms of internal consistency. In particular, when examining the distribution of the (quantitively) assessed levels of resilience and sustainability (see Fig. 7.7), it was possible to observe a predominance of the most desirable levels, although the distribution was not homogeneous throughout the region, but rather highly scattered. When considering the river basins, the condition of the Esino basin appeared especially interesting, as here all the assessed levels were represented.

Overall, floods are especially relevant to the Esino basin. The Italian law (*D.P.C.M. 29/09/1998*, n.d.) recognises four classes of flood risk, depending on the return time of the probable flood: moderate – medium – high – very high (R1 to R4, respectively), with expected damages growing consistently through the classes. In the Esino river basin, most areas fall under the classes R2 (35.50%) and R4 (25.80%), respectively representing the 0.7% and the 0.4% of the total surface of the basin (*Piano stralcio di* *bacino per l'Assetto Idrogeologico dei bacini di rilievo regionale (PAI) 21.01.2004*, 2004). Although the values are in line with the averages related to the Marche region, the relative wight of the R4 flood risk class represents a higher threat compared to the remaining region. Indeed, in the last years a series of events affected the municipalities of this river basin. A mean of 2.73 events occurred in these municipalities in the studied period, although nearly 38% of the municipalities suffered from a flood event almost once a year, estimation that grows past 55% when considering a recurrence of at least three times in the five years period.

All these considerations appear to confirm the suitability of the Esino river basin as a case study to investigate the impact of floods on the development of the local communities. Hence, the selection of the suitable municipalities followed, aided by the distribution of the levels of resilience and sustainability. Overall, the possible levels are nine: the LR-LS level was excluded because absent in the Marche case study; the HR-LS and the LR-HS levels were excluded as well because they were assumed as *traps*, thus needing to be treated as a separate matter. Consequently, a total of six municipalities were needed to represent all the remaining levels (Tab. 12.1).

Tab. 12.1 - Combined levels (high H, medium M, low L) of resilience (R) and of sustainability (S) along with the selected municipalities of the Esino river basin

Level of Resilience and Sustainability	*Municipality*
HR-HS	Jesi
HR-MS	Serra San Quirico
MR-HS	San Marcello
MR-MS	Fabriano
MR-LS	Falconara Marittima
LR-MR	Genga

The selected municipalities (Fabriano, Falconara Marittima, Genga, Jesi, San Marcello, Serra San Quirico) are distributed throughout the basin, from upstream towards downstream until the coast, following the course of the Esino river (Fig. 12.1). Except for Serra San Quirico, which was affected just once, all these municipalities regularly suffered from flood impacts, at least 3 times, but more frequently 4 times (4 out of 6 municipalities) in 5 years.

The questionnaire was made available in both Italian and English language, to facilitate the participation of respondents. As previously mentioned, the population sampling intended to adhere to the probability-driven techniques, since the present objective focuses on the general perception of the level of resilience and sustainability of a municipality. In

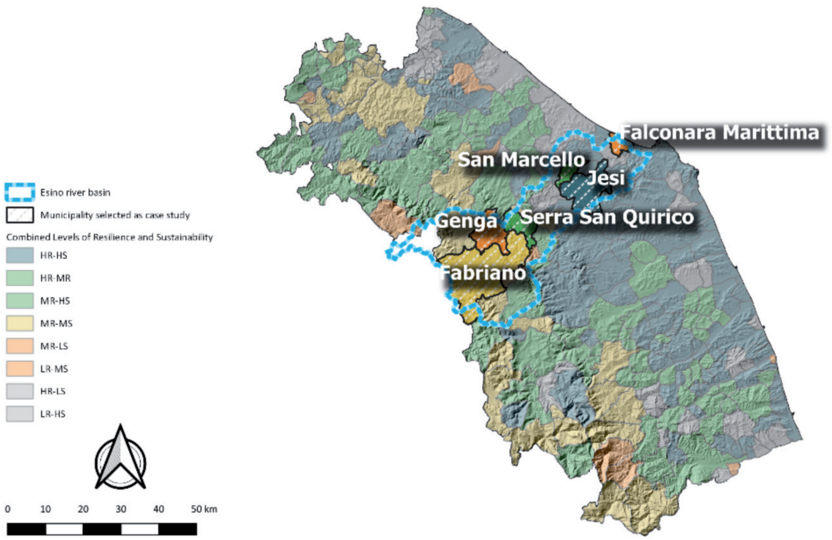


Fig. 12.1 - The Esino river basin and the selected municipalities within the Marche region

particular, questionnaires were administered thorough a double channel: telephone calls and an online form. In the first case, the telephone directory was consulted. The first and the last name of each column was selected, excluding same surnames, as they might lead to members of the same family and thence introduce a possible bias; if there were not enough columns, the selection proceeded along the available ones. Approximately 10 names per each letter were first targeted, though when the telephone number resulted not active, a substitute was included, avoiding a far as possible to repeat surnames also in this case. Only telephone numbers that referred to households were considered. Telephone numbers were dialled at least twice when it was not possible to obtain an answer in the first attempt. When reaching a respondent, the questionnaire was read and the answers registered manually. In these cases, if further discussions and thoughts were shared, they were recorded as well. Before starting, it was offered the option to receive via e-mail the link to the online questionnaire, in case it was more convenient for the respondent. In general, the online questionnaire was publicised through social media (Facebook shares in personal profile and groups relevant to the local communities). In addition, some key persons related to local cultural associations supported the diffusion. Despite the effort to maximise the representativeness of the sample, it is acknowledged here that some biases might be introduced. For instance, the historical socio-demographic features of the region might lead to a prevalence of women staying at home, decreasing the probability of interacting with men. At the same time, although common, the registration in the telephone directory is not mandatory, hence the list probably does not include the whole population. Similarly, although the employed social media is highly popular, it might not reach the entirety of the local communities. Though it is evident that these restrains might hamper the reliability of the sampling, the mixed technique and the number of respondents sought to compensate for those drawbacks.

13. Results

In the following paragraphs, the results of the application of the last phase of the CAReS+ (enhanced Combined Assessment of Resilience and Sustainability) methodology will be presented. This phase involved a selection of municipalities of the Marche region, representative of the previously assessed levels of resilience and sustainability. Following the introduction of the overall gathered responses, the discussion will be divided into two main parts: first, some considerations pertaining the municipalities as a whole, thence the information could be considered as an averaged value over the Municipal population; then, some considerations associated to the answer of each respondent (independently of the related municipality), thence the information could be assumed as an averaged value over the level, perceived or assessed, of resilience, sustainability or combined.

13.1. Introduction of the local responses

As previously mentioned, questionnaires were delivered through a double channel, that is via phone administration and through an online form. The collected information concerned resilience and sustainability themes as well as demographic variables. In addition to providing information for the discussion to come, the latter allows also to delineate the main characteristics of the respondent population. The overall results, distinguished per municipality, will be thoroughly presented: here, the discussion will proceed following the thematic sections of the questionnaire. Later, the focus will be directed only towards the analyses of the responses that held a peculiar or unexpected meaning.

13.1.1. *Assessment of the perceived level of resilience*

The first section of the questionnaire was intended to draw the perceived level of resilience. For this purpose, the questions and the available choices mirrored as far as possible the previous quantitative assessment. In general terms, respondents were questioned on themes related to resilience capacities, as well as the observed implementation in critical conditions (Tab. 13.1).

Tab. 13.1 - Number of preferences per each question and each related level (low L, medium M, high H) of resilience (R), per each municipality

Answers	*Options*	*Corresponding level*	*Municipality* *Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
Effect of flood risk on:								
		1. Social cohesion						
Valid	Worse	LR	3	4	0	2	1	3
	As usual	MR	14	16	7	19	16	12
	Better	HR	2	2	6	5	0	1
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
		2. Household income						
Valid	Worse	LR	5	8	4	10	3	2
	As usual	MR	13	13	8	15	13	14
	Better	HR	0	1	1	1	1	0
	Total		18	22	13	26	17	16
Missing			1	0	0	0	0	0
Total			19	22	13	26	17	16
		3. Infrastructural development						
Valid	Worse	LR	4	6	1	4	4	0
	As usual	MR	11	13	6	16	12	13
	Better	HR	3	2	6	6	1	3
	Total		18	21	13	26	17	16
Missing			1	1	0	0	0	0
Total			19	22	13	26	17	16
		4. Flood management activities						
Valid	Less activities	LR	5	7	5	5	7	5
	As usual	MR	8	9	6	15	9	8
	More activities	HR	6	5	1	6	1	3
	Total		19	21	12	26	17	16
Missing			0	1	1	0	0	0
Total			19	22	13	26	17	16
		5. Number of flood-proof buildings and infrastructures						
Valid	Lower	LR	3	6	2	6	2	2
	As usual	MR	12	13	8	19	14	14
	Higher	HR	3	2	3	1	1	0
	Total		18	21	13	26	17	16

Missing			1	1	0	0	0	0
Total			19	22	13	26	17	16
6. My fellow citizens have become more aware of flood risk								
Valid	Disagree	LR	6	11	5	7	5	1
	Uncertain, neutral	MR	4	4	4	13	6	5
	Agree	HR	9	7	4	6	6	10
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
7. I have become more aware of flood risk								
Valid	Disagree	LR	4	1	2	3	4	0
	Uncertain, neutral	MR	4	6	2	11	2	1
	Agree	HR	11	15	9	12	11	15
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
8. The citizens of my municipality have enough means and sources to manage a flood emergency								
Valid	Disagree	LR	13	17	6	16	4	8
	Uncertain, neutral	MR	2	3	4	7	9	5
	Agree	HR	4	2	3	3	4	3
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
Effect of last flood on:								
9. Population growth in flooding areas								
Valid	Less people	HR	7	4	6	9	2	2
	As usual	MR	11	14	6	15	15	14
	More people	LR	1	3	1	2	0	0
	Total		19	21	13	26	17	16
Missing			0	1	0	0	0	0
Total			19	22	13	26	17	16
10. Economic welfare								
Valid	Worse	LR	8	9	1	10	4	1
	As usual	MR	10	13	12	15	13	15
	Better	HR	0	0	0	1	0	0
	Total		18	22	13	26	17	16
Missing			1	0	0	0	0	0
Total			19	22	13	26	17	16
11. Amount of damage								
Valid	Low	HR	13	9	2	11	9	7
	Not high not low	MR	3	6	6	10	5	5
	High	LR	3	7	5	5	3	4
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
12. Recovery of social life and public services								
Valid	Absent	LR	1	2	2	3	0	1
	Partial	MR	10	13	3	14	4	6
	Complete	HR	8	7	8	9	13	9
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
13. Duration of recovery of social life and public services								

Valid	Long	HR	4	5	3	2	1	3
	Not long not short	MR	5	10	7	13	7	9
	Short	LR	10	7	3	11	9	4
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
		14. Return to everyday life						
Valid	Absent	LR	1	0	1	0	0	0
	Partial	MR	5	12	3	15	4	6
	Complete	HR	13	10	9	11	13	10
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
	16. Local authorities have become able to effectively manage a flood emergency							
Valid	Disagree	LR	6	10	5	8	2	5
	Uncertain, neutral	MR	7	7	5	13	9	2
	Agree	HR	6	5	3	5	6	9
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
	17. My fellow citizens have become able to effectively manage a flood emergency							
Valid	Disagree	LR	7	12	3	10	2	7
	Uncertain, neutral	MR	7	7	7	15	9	3
	Agree	HR	5	3	3	1	6	6
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16
	18. I have become able to effectively manage a flood emergency							
Valid	Disagree	LR	8	8	4	10	3	5
	Uncertain, neutral	MR	7	8	5	13	7	4
	Agree	HR	4	6	4	3	7	7
	Total		19	22	13	26	17	16
Missing			0	0	0	0	0	0
Total			19	22	13	26	17	16

The participation to this section was rather high, with few missing responses. Similarly, preferences were distributed throughout the available options, with few cases of no selected option (e.g. question *1. Social cohesion*, option "*better*" for respondents from San Marcello), even though the distribution was generally not homogenous.

13.1.2. *Assessment of the perceived level of sustainability*

This section was complementary to the previous one, pursuing the aim of drawing the perceived level of sustainability of the selected municipalities. Also in this case the proposed themes mirrored those included in the previous quantitative assessment, being the impact of anthropic activities on the surrounding environment (Tab. 13.2).

Tab. 13.2 - Number of preferences per each question and each related level (low L, medium M, high H) of sustainability (S), per each municipality

Answers	*Options*	*Corresponding level*	*Municipality* Fabriano	Falconara Marittima	Genga	Jesi	San Marcello	Serra San Quirico
		19. Transformation of green areas						
Valid	Smaller	LS	6	2	0	4	4	1
	As usual	MS	9	15	10	16	12	8
	Wider	HS	4	4	3	6	1	7
	Total		19	21	13	26	17	16
Missing			0	1	0	0	0	0
Total			19	22	13	26	17	16
		20. Land use change						
Valid	Low	HS	8	8	5	6	10	10
	Average	MS	7	9	5	12	5	6
	High	LS	4	4	3	8	2	0
	Total		19	21	13	26	17	16
Missing			0	1	0	0	0	0
Total			19	22	13	26	17	16
		21. Quantity of urban and industrial use of water						
Valid	Lower	HS	8	1	1	3	2	4
	As usual	MS	9	13	7	17	8	9
	Higher	LS	1	7	5	6	6	3
	Total		18	21	13	26	16	16
Missing			1	1	0	0	1	0
Total			19	22	13	26	17	16
		22. Characteristics of the river area						
Valid	Worse	LS	5	6	3	3	6	5
	As usual	MS	8	10	6	20	11	9
	Better	HS	6	4	4	2	0	2
	Total		19	20	13	25	17	16
Missing			0	2	0	1	0	0
Total			19	22	13	26	17	16
		23. Soil fertility						
Valid	Lower	LS	5	5	4	9	3	5
	As usual	MS	11	12	8	14	6	9
	Higher	HS	2	4	1	2	6	2
	Total		18	21	13	25	15	16
Missing			1	1	0	1	2	0
Total			19	22	13	26	17	16
		24. Wildlife catches						
Valid	Lower	LS	8	7	1	7	4	2
	As usual	MS	7	10	3	15	7	5
	Higher	HS	3	3	9	3	2	8
	Total		18	20	13	25	13	15
Missing			1	2	0	1	4	1
Total			19	22	13	26	17	16
		25. Landscape scenery						

Valid	Worse	LS	4	11	5	5	4	1
	As usual	MS	11	9	5	17	8	9
	Better	HS	4	1	3	3	5	6
	Total		19	21	13	25	17	16
Missing			0	1	0	1	0	0
Total			19	22	13	26	17	16
26. Number of species in dangerous conditions								
Valid	Low	HS	6	7	6	4	7	4
	Average	MS	10	9	6	18	7	11
	High	LS	3	4	1	3	1	1
	Total		19	20	13	25	15	16
Missing			0	2	0	1	2	0
Total			19	22	13	26	17	16
27. Effects of human activities on rivers and streams								
Valid	Negative	LS	9	12	2	8	9	4
	Not negative not positive	MS	5	4	8	11	2	3
	Positive	HS	5	5	3	6	3	9
	Total		19	21	13	25	14	16
Missing			0	1	0	1	3	0
Total			19	22	13	26	17	16
28. Protection of natural areas								
Valid	Insufficient	LS	4	7	4	4	2	2
	Inadequate and no possi-bility of changes	LS	5	2	1	5	5	5
	Inadequate, but changes are happening	MS	5	8	0	7	2	3
	Significant	HS	3	3	6	9	6	6
	Total		17	20	11	25	15	16
Missing			2	2	2	1	2	0
Total			19	22	13	26	17	16
29. Initiatives to reduce pollution								
Valid	Insufficient	LS	4	13	4	10	5	4
	Inadequate and no possi-bility of changes	LS	5	4	2	1	3	5
	Inadequate, but changes are happening	MS	5	3	4	11	4	5
	Significant	HS	3	1	3	3	3	2
	Total		17	21	13	25	15	16
Missing			2	1	0	1	2	0
Total			19	22	13	26	17	16

Similarly to the previous case, the participation to this section was rather high in terms of responses. The distribution of preferences was rather diverse, although not particularly even.

13.1.3. *Critical functions and thresholds of resilience and of sustainability*

This section of the questionnaire aimed at gathering the perception of the local communities on the characterising traits of their local social-ecological system. In other words, the purpose was to allow local populations to identify and possibly quantify the most significant functions (Tab. 13.3) and thresholds (Tab. 13.4) related to the adaptive cycles composing their local Social-Ecological Panarchy.

Tab. 13.3 - Number of preferences per each question concerning the critical functions of resilience and sustainability, per each municipality

		Municipality						
Answers	*Options*	*Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	30. Most important functions for resilience							
Valid	Productive system	13	7	5	12	4	1	42
	Banking/financial services	2	0	0	1	0	0	3
	Energy system	5	4	2	5	4	7	27
	Transportation system	5	3	4	4	1	7	24
	Water system	9	6	2	6	5	6	34
	Sewage system	4	7	0	3	1	1	16
	Waste disposal system	7	8	1	5	5	4	30
	Health system	8	12	7	14	12	9	62
	Police service	1	5	2	6	4	1	19
	Education system	7	12	5	7	4	0	35
	Communication system	1	1	0	1	0	1	4
	Social life	1	2	2	3	1	0	9
	Total	18	21	13	25	15	15	107
Missing		1	1	0	1	2	1	6
Total		19	22	13	26	17	16	113
	34. Most important functions for sustainability							
Valid	Food production	12	7	7	18	11	10	65
	Raw materials production	3	5	2	7	4	4	25
	Soil formation	3	5	1	3	3	1	16
	Clean air supply	13	21	9	13	5	10	71
	Clean water supply	16	19	12	20	11	11	89
	Precipitation regulation	0	1	0	1	0	1	3
	Scenery	2	4	4	4	3	3	20
	Total	18	21	13	25	15	14	106
Missing		1	1	0	1	2	2	7
Total		19	22	13	26	17	16	113

Tab. 13.4 - Number of preferences per each question and the main critical thresholds of resilience and sustainability, per each municipality

Answers	*Options*	*Municipality* Fabriano	Falconara Marittima	Genga	Jesi	San Marcello	Serra San Quirico
Resilience							
	31. Maximum acceptable duration of recovery						
Valid	Up to 1 day	2	7	4	5	5	2
	Up to 1 month	1	3	0	5	1	1
	Up to 1 week	4	4	6	5	3	4
	Few hours	11	7	3	10	6	8
	Total	18	21	13	25	15	15
Missing		1	1	0	1	2	1
Total		19	22	13	26	17	16
	32. Acceptable quality after recovery						
Valid	Worse	1	1	0	1	0	0
	As before	4	4	4	12	9	8
	Better	13	16	9	12	6	7
	Total	18	21	13	25	15	15
Missing		1	1	0	1	2	1
Total		19	22	13	26	17	16
	33. Duration of alternative sources to cope with critical function interruption						
Valid	Up to 1 day	4	6	5	4	3	3
	Up to 1 month	3	2	3	1	3	2
	Up to 1 week	5	10	4	13	5	5
	Few hours	6	3	1	7	3	5
	Total	18	21	13	25	14	15
Missing		1	1	0	1	3	1
Total		19	22	13	26	17	16
Sustainability							
	35. Maximum acceptable duration of recovery						
Valid	20 years	0	0	0	0	2	0
	10 years	0	3	0	1	0	2
	5 years	16	17	13	21	12	12
	Impossible	0	1	0	2	0	0
	No need	1	0	0	1	0	0
	Total	17	21	13	25	14	14
Missing		2	1	0	1	3	2
Total		19	22	13	26	17	16
	36. Acceptable quality after recovery						
Valid	Worse	1	0	1	0	0	0
	As before	3	5	3	10	6	5
	Better	14	16	9	15	8	9
	Total	18	21	13	25	14	14
Missing		1	1	0	1	3	2
Total		19	22	13	26	17	16
	37. Acceptable loss						
Valid	Until you can compensate for them	6	7	4	5	3	6
	Until you can make use of them	0	2	2	4	1	2
	None	12	12	6	16	11	4
	All	0	0	1	0	0	1
	Total	18	21	13	25	15	13
Missing		1	1	0	1	2	3
Total		19	22	13	26	17	16

Also in this section of the questionnaire, the missing cases are rather low, when considering both functions and thresholds of the complex social-ecological system. In the case of resilience functions, all options received preferences, except for the case of *banking and financial services* and the *communication system* that were chosen only 3 and 4 times (out of the 107 total expressed preferences), respectively. Conversely, the case of sustainability was more consistent, as *water*, *air* and *food* received the wide majority of the preferences, while *precipitation regulation* gathered the lowest consensus (3 total preferences out of the 106 expressed).

A similar trend might be observed when examining the preferences concerning the thresholds. Indeed, the thresholds concerning resilience were less defined than those pertaining to sustainability, where preferences were evidently polarised towards the lowest tolerance of loss and endangerment.

13.1.4. *Socio-demographic features*

The last section of the questionnaire drew the characterisation of the responding population. Themes concerned the common demographic and social features, as well as economic traits and available assets (Tab. 13.5).

Tab. 13.5 - Number of preferences per each question related to the socio-demographic features of the responding population, per each municipality

		Municipality					
Answers	*Options*	*Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
	38. Place of birth						
Valid	Africa	0	0	0	0	0	0
	America	0	0	0	0	0	1
	Asia	0	0	0	0	0	0
	Europe (other than Italy)	1	0	1	0	1	0
	Italy	18	21	12	25	14	15
	Oceania	0	0	0	0	0	0
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
	39. Gender identified with						
Valid	Female	15	9	9	15	7	11
	Male	4	13	4	11	10	5
	Total	19	22	13	26	17	16
Missing		0	0	0	0	0	0

Total		19	22	13	26	17	16
	40. Class of age						
Valid	Less than 18 years old	0	0	0	0	0	0
	18-24 years old	1	2	1	4	2	1
	25-34 years old	3	4	1	3	1	2
	35-44 years old	0	5	1	0	1	0
	45-54 years old	4	3	4	7	2	0
	55-64 years old	5	2	3	6	4	6
	65-79 years old	6	5	2	5	5	5
	Over 80 years old	0	0	1	0	2	2
	Total	19	21	13	25	17	16
Missing		0	1	0	1	0	0
Total		19	22	13	26	17	16
	41. Highest level of education						
Valid	Primary school	1	1	1	1	1	3
	Middle school	2	2	0	2	4	5
	High school	7	9	7	9	6	5
	Bachelor's degree or equivalent	0	2	2	3	1	1
	Master's degree or equivalent	7	6	3	7	3	2
	Post-graduate degree, Doctoral degree or equivalent	2	1	0	3	0	0
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
	42. Municipality of residence						
Valid	Fabriano	19	0	0	0	0	0
	Falconara Marittima	0	22	0	0	0	0
	Genga	0	0	13	0	0	0
	Jesi	0	0	0	26	0	0
	San Marcello	0	0	0	0	17	0
	Serra San Quirico	0	0	0	0	0	16
	Total	19	22	13	26	17	16
Missing		0	0	0	0	0	0
Total		19	22	13	26	17	16
	43. Permanence in municipality of residence						
Valid	1 year or less	0	1	0	1	0	0
	2-5 years	0	1	0	0	0	0
	5-10 years	1	0	0	0	1	0
	More than 10 years	18	19	13	24	14	16
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
	44. Number of cohabitants						
Valid	1	1	4	1	4	0	2
	2	6	6	5	7	4	7
	3-4	11	10	5	9	7	6
	More than 4	1	1	2	4	4	1
	Total	19	21	12	24	15	16
Missing		0	1	1	2	2	0
Total		19	22	13	26	17	16
	45. Presence of minors among cohabitants						
Valid	No	14	19	10	19	10	15
	Yes	5	2	3	6	5	1
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16

		46. Local civic organisation participation					
Valid	No	15	12	10	13	10	13
	Yes	4	9	3	12	5	3
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
		47. National election participation					
Valid	No	0	0	0	4	2	2
	Yes	19	21	13	21	13	14
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
		48. Current employment					
Valid	No	8	6	3	11	6	8
	Yes	11	15	10	14	9	8
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
		49. Class of income					
Valid	0-15 000€	6	1	5	6	4	11
	15 001-30 000€	10	13	5	9	5	3
	30 001-50 000€	2	3	3	4	2	2
	More than 50 000€	0	0	0	4	1	0
	Total	18	17	13	23	12	16
Missing		1	5	0	3	5	0
Total		19	22	13	26	17	16
		50. Ownership of phone					
Valid	No	2	0	0	0	3	1
	Yes	17	21	13	25	12	15
	Total	19	21	13	25	15	16
Missing		0	1	0	1	2	0
Total		19	22	13	26	17	16
		51. Ownership of personal means of transportation					
Valid	No	3	2	1	2	0	2
	Yes	16	19	12	23	14	14
	Total	19	21	13	25	14	16
Missing		0	1	0	1	3	0
Total		19	22	13	26	17	16
		52. Internet access at home					
Valid	No	3	1	1	2	1	4
	Yes	16	20	12	23	13	12
	Total	19	21	13	25	14	16
Missing		0	1	0	1	3	0
Total		19	22	13	26	17	16
		53. Average data speed at home					
Valid	Less than 2 mb/s	1	0	5	1	0	1
	More than 2 Mb/s	2	4	6	4	5	2
	More than 20 Mb/s	3	5	1	5	1	1
	More than 50 Mb/s	5	4	0	5	2	1
	More than 100 Mb/s	2	4	0	6	0	0
	Total	13	17	12	21	8	5
Missing		6	5	1	5	9	11
Total		19	22	13	26	17	16
		54. Ownership of house					
Valid	No	5	4	2	6	3	1
	Yes	14	16	11	18	11	15

	Total		19	20	13	24	14	16
Missing			0	2	0	2	3	0
Total			19	22	13	26	17	16
		55. Age of house						
Valid	1918 or before		3	0	0	4	4	0
	1919-1945		0	4	1	0	0	1
	1946-1960		2	2	0	0	5	3
	1961-1970		1	6	4	5	0	2
	1971-1980		2	6	0	5	1	4
	1981-1990		5	3	3	6	1	6
	1991-2000		3	0	2	3	1	0
	2001-2005		1	0	2	2	1	0
	2006 or after		1	0	0	0	0	0
	Total		18	21	12	25	13	16
Missing			1	1	1	1	4	0
Total			19	22	13	26	17	16

Although even in this case the rate of response was high, some themes raised some diffidence, hence the willingness to answer resulted lower. This happened for economic themes, especially when related to the *class of income* (question n° 49). At the same time, *internet speed* (question n° 53) was rarely addressed, although this might be due to an unawareness of the actual capacity of their network.

13.1.5. *Additional information*

Throughout the questionnaire, some additional questions were included, with the aim of collecting further information on the dynamics occurring in the selected municipalities (Tab. 13.6, Tab. 13.7, Tab. 13.8, Tab. 13.9 and Tab. 13.10). Notably, not all of these questions were mandatory, hence the rate of response was expected to be lower than in the other cases. Furthermore, some of these questions allowed a multiple choice of answers.

In terms of the most frequent measures of flood risk reduction, activities pertaining the river (31 preferences out of total 131) or its embankments (26 preferences out of total 131) gathered the majority of the preferences, followed by the management of the drainage system (23 preferences out of total 131). On the contrary, the design and adoption of flood maps was not particularly witnessed (3 preferences out of total 131).

Notably, respondents were asked to indicate only the activities performed within their own municipality, hence options related to the seacoasts (*coastal defence* and *coastal maintenance*) were expected to be more rarely selected, given that only one municipality (Falconara Marittima) lies on the seaside. Nevertheless, in this case, such options were indicated by 7 and 9 respondents, respectively, out of the 36 total expressed preferences.

Tab. 13.6 - Number of preferences per most common flood management activity, per each municipality

Answers	*Options*	*Municipality* *Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	4.1 most common management activities							
Valid	Construction and management of embankments	3	5	3	8	1	6	26
	River management	4	6	5	11	1	4	31
	Drainage system management	4	4	3	6	4	2	23
	Coastal defence	0	7	0	0	0	0	7
	Coastal maintenance	1	9	0	2	0	0	12
	Urban development planning	2	2	0	6	1	1	12
	Flood-related maps	1	0	0	1	0	1	3
	Early warning systems	5	3	2	6	1	0	17
	Total	20	36	13	40	8	14	131
Total respondents		12	16	8	20	4	7	67
Missing respondents		7	6	5	6	13	9	46
Total		19	22	13	26	17	16	113

Tab. 13.7 - Number of preferences per asset that would suffer more damages due to a flood, per each municipality

Answers	*Options*	*Municipality* *Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	11.1 which would suffer more damages							
valid	public buildings	0	0	3	3	2	2	10
	private buildings	8	13	8	16	2	8	55
	productive system	5	9	6	10	6	6	42
	energy system	2	0	2	3	1	0	8
	banking/financial services	1	1	0	0	0	0	2
	communication system	3	1	1	0	2	0	7
	transportation system	5	6	6	8	4	2	31
	health system	0	0	1	0	0	0	1
	water system	4	7	1	3	1	1	17
	sewage system	6	6	1	6	2	2	23
	waste disposal system	0	0	1	2	0	2	5
	none	0	0	0	0	2	0	2
	total	34	43	30	51	22	23	203
total respondents		14	17	13	24	14	10	92
missing respondents		5	5	0	2	3	6	21
total		19	22	13	26	17	16	113

In the context of the potential impact of a flood, respondents were surveyed on the perceived susceptibility of local assets (Tab. 13.7). Preferences converged towards *private buildings* and the *productive system* (55 and 42 preferences out of total 203), whereas *banking and financial services* received the lowest agreement. Notably, respondents rarely assumed that no assets would be damaged (option *none*, 2 preferences out of the total 203) and when this occurred, it pertained only one municipality (San Marcello).

Tab. 13.8 - Number of preferences per each question concerning awareness of local flood management plans, per each municipality

Answers	*Options*	*Municipality*						
		Fabriano	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	15. Knowledge of local and regional flood management plans							
Valid	Municipal Civil Protection Plan	6	10	4	8	1	1	30
	Flood Risk Management Plan	2	4	1	3	1	0	11
	River Contract	0	1	1	4	0	1	7
	None of the above	13	12	9	16	16	14	80
	Other	0	1	2	0	0	0	3
	Total	21	28	17	31	18	16	131
Total respondents		19	22	13	26	17	16	113
Missing respondents		0	0	0	0	0	0	0
Total		19	22	13	26	17	16	113
	15.1 Level of knowledge of local and regional flood management plans							
Valid	I have read it/them	2	4	1	2	1	2	12
	I have attended discussions about it/them	2	4	0	6	0	0	12
	I have heard about it/them	2	4	2	3	0	0	11
Total respondents		6	12	3	11	1	2	35
Missing respondents		13	10	10	15	16	14	78
Total		19	22	13	26	17	16	113
	15.2 Source of knowledge of local and regional flood management plans							
Valid	By word of mouth among acquaintances	1	3	2	3	0	0	9
	Television and/or radio	1	0	0	0	0	0	1
	Books and/or magazines and/or newspapers	1	0	0	3	0	0	4
	Websites and/or social media	0	3	0	1	0	1	5
	Websites and/or social media of public authorities	1	4	0	2	0	0	7
	Mails and/or e-mails from public authorities	0	1	0	0	0	0	1
	Activities and/or flyers of public authorities	1	1	1	1	1	1	6
Total respondents		5	12	3	10	1	2	33
Missing respondents		14	10	10	16	16	14	80
Total		19	22	13	26	17	16	113

It was also possible to investigate the awareness on the local plans and strategies to manage flood risk and emergency (Tab. 13.8). In general terms, it appears that the familiarity with this kind of strategic planning is rather limited, as most of the respondents admitted of not being knowledgeable of any (question *15*, option *none of the above*, 80 preferences of the total 131). In the remaining cases, local Civil Protection Plans (question *15*, option *Municipal Civil Protection Plan*, 30 preferences of the total 131) were the most known, although the level of detail was heterogeneous (question *15.1*). The most common means of first information appeared to be a discussion with relatives or acquaintances, followed by official communications delivered by the local authorities through their websites and social media (question *15.2*, option *by word of mouth among acquaintances* and *websites and/or social media of public authorities*, 9 and 7 preferences of the total 33 respectively).

Tab. 13.9 - Number of preferences per personal capacities in dealing with flood emergency, per each municipality

		Municipality						
Answers	*Options*	*Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	18.1 reason of personal efficacy in flood emergency management							
Valid	I learnt the emergency procedures	2	6	2	7	1	2	20
	I survived the last flood	0	1	1	1	0	0	3
	I am sure that I will get help	5	4	3	4	1	2	19
Total respondents		7	11	6	12	2	4	42
Missing respondents		12	11	7	14	15	12	71
Total		19	22	13	26	17	16	113

In case respondents had previously positively assessed their abilities to manage flood events (question *18*), they were asked for a justification (*18.1*). In this case (Tab. 13.9), preference were almost equally divided between acquired abilities and provided assistance (option *I learnt the emergency procedures* and *I am sure that I will get help*, 20 and 19 preferences of the total 42 respectively). Conversely, it appears that the last flood event did not leave any beneficial effect in this context (option *I survived the last flood*, 3 preferences of the total 42).

Tab. 13.10 -Number of preferences per typology of land use change, per each municipality

Answers	*Options*	*Municipality* *Fabriano*	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*	*Total*
	20.1 Most frequent type of land use change							
Valid	Urbanisation	9	11	3	15	6	2	46
	Industrialisation	1	4	1	2	0	2	10
	Naturalisation	2	2	3	5	1	3	16
	Total	12	17	7	22	7	7	72
Missing		7	5	6	4	10	9	41
Total		19	22	13	26	17	16	113

A side question was included also for the sustainability domain (Tab. 13.10). In this case, the theme concerned the alteration of the surrounding landscape. It emerged that anthropic activities are perceived to cause the most frequent transformations, especially in terms of urban settlements (46 preferences out of total 72). Notably, even though limited, also the conversion to natural areas was reported by a significant share of respondents (16 preferences out of total 72).

13.2. Analysis of the Municipal response

The present section is aimed at investigating the local perception aggregated per pertaining municipality of the respondent. The first part outlines the structure of the responding population (Tab. 13.11).

A total of 113 questionnaires were collected, almost evenly distributed among the municipalities (Fig. 13.1), with Jesi holding the highest portion (26 questionnaires, 23% of the total) and Genga the lowest one (13 questionnaires, 12% of the total). This distribution mirrors to the different dimension of the corresponding populations (Tab. 13.11), as for instance Jesi hosts the largest population (40210 residents), conversely to Genga, which hosts the smaller (1748 residents).

Tab. 13.11 - Main characteristics of the respondent population per surveyed municipalities, including the related assessed combined level of resilience and sustainability

		Municipality					
		Fabriano	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
Combined assessed level of resilience and sustainability		MR-MS	MR-LS	LR-MS	HR-HS	MR-HS	HR-MS
Population (2018)		30809	26063	1748	40210	2036	2744
Number of questionnaires (total = 113)		19	22	13	26	17	16
Gender	*Female*	15	9	9	14	7	11
	Male	4	13	4	11	10	5
Most frequent class of	*Age*	65-80	35-44; 65-80	45-54	45-54	65-80	55-64
	Education	High school; Master's degree or equivalent	High school	High school	High school	High school	Middle school; High school
	Income	15 001-30 000€	15 001-30 000€	15 001-30 000€	15 001-30 000€	15 001-30 000€	0-15 000€
	Residence	more than 10 years	more than 10 years	more than 10 years	more than 10 years	more than 10 years	more than 10 years

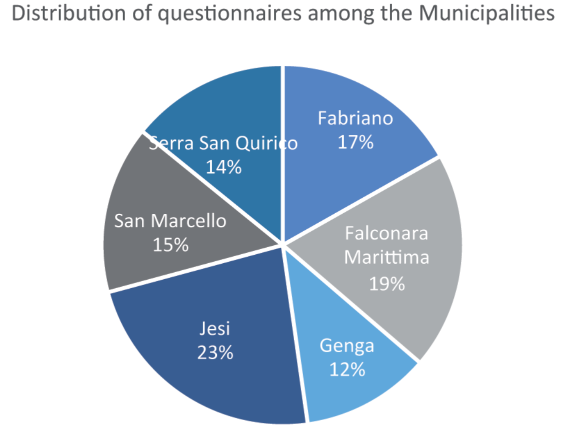


Fig. 13.1 - Portion of the collected questionnaires per each surveyed municipality

Overall, the majority of the respondents declared a female gender, except for the municipalities of Falconara Marittima and of San Marcello, whose respondents were mainly of male gender (Fig. 13.2).

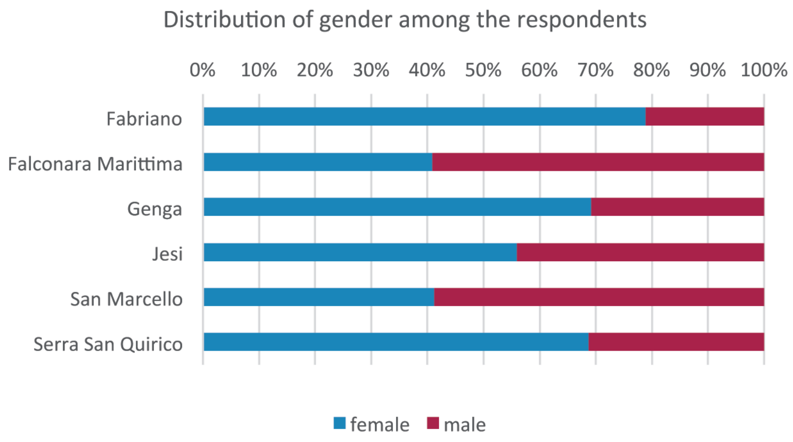


Fig. 13.2 - Portion of each gender among the respondents per each surveyed municipality

The respondents were distributed among all the classes of age, though some classes were not always represented (Fig. 13.3). In general, the more adult classes were dominant (45-54 to 65-80 years old), except for Falconara Marittima (35-44 years old).

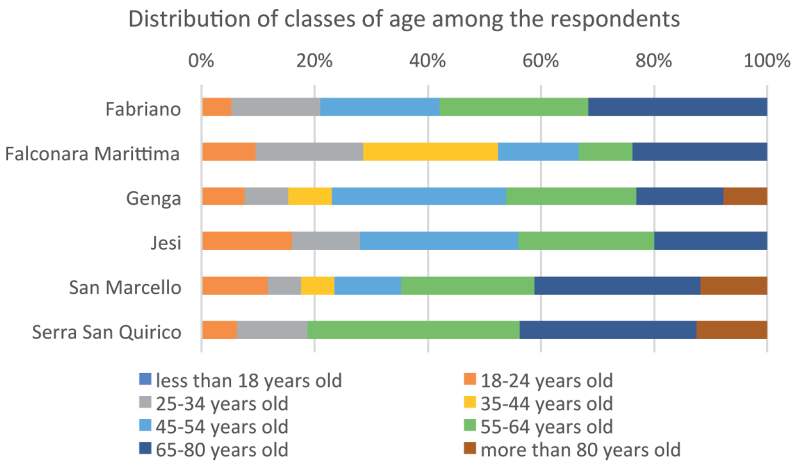


Fig. 13.3 - Portion of each class of age among the respondents per each surveyed municipality

In general terms, most of the respondents declared to have achieved a level of education corresponding to high school, although the respondents of Fabriano equally declared a Master's degree (or equivalent) and those from Serra San Quirico a middle school level (Fig. 13.4).

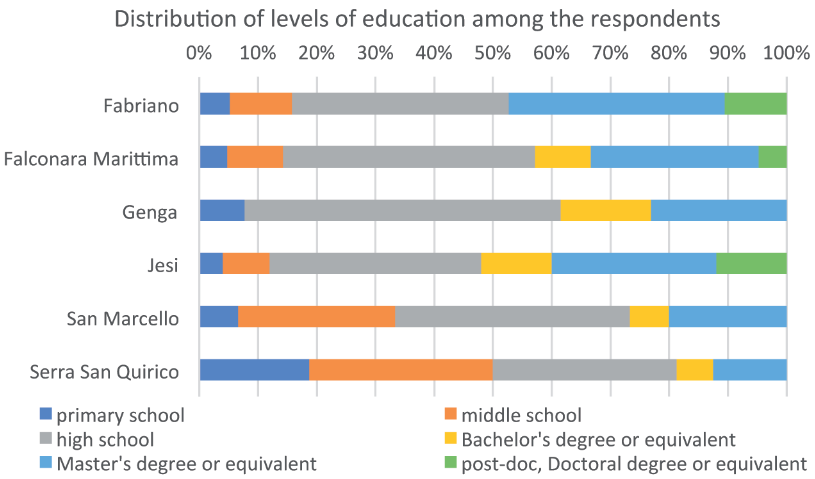


Fig. 13.4 - Portion of each level of education among the respondents per each surveyed municipality

The respondents resulted rather homogeneous in terms of income, as the majority was distributed between the first two levels (0-15000€ and 15001-30000€), especially for Fabriano and Serra San Quirico (Fig. 13.5).

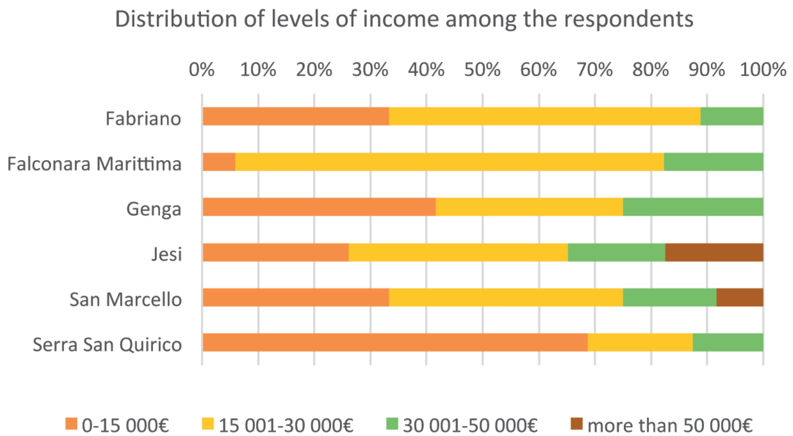


Fig. 13.5 - Portion of each level of income among the respondents per each surveyed municipality

Similarly, almost all respondents affirmed to have spent in their municipality an extensive period of their life, generally over 10 years (Fig. 13.6). Only the respondents related to the municipality of Falconara Marittima proposed a slightly higher variance, though still limited.

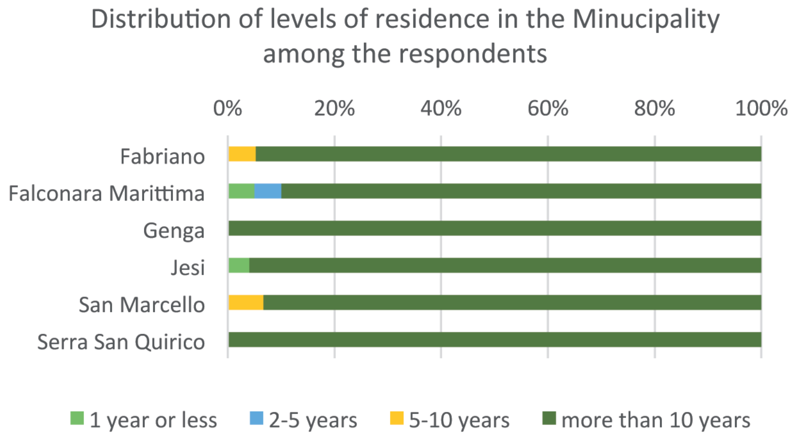


Fig. 13.6 - Portion of each level of residence among the respondents per each surveyed municipality

A further priority of this phase was the identification of the perceived levels of resilience and of sustainability, as well as the definition of critical functions and related thresholds, concerning both *cores* (Tab. 13.12).

Tab. 13.12 - Perceived levels (low L, medium M, high H) of resilience (R) and of sustainability (S), perceived critical functions, identified thresholds of recovery and of collapse, preferred quality after recovery of the critical functions, per each surveyed municipality

		Municipality					
		Fabriano	*Falconara Marittima*	*Genga*	*Jesi*	*San Marcello*	*Serra San Quirico*
Level of	*Resilience*	MR	MR	MR	MR	MR	MR
	Sustainability	MS	MS	MS	MS	MS	MS
Resilience	*Critical functions ("s." for "system")*	productive s. water s. health s.	health s. education s. waste disposal s.	health s. productive s. education s.	health s. productive s. education s.	health s. waste disposal s. water s.	health s. energy s. transportation s.
	Threshold of recovery	few hours	few hours up to 1 day	up to 1 week	few hours	few hours	up to 1 week
	Quality after recovery	better	better	better	same better	same	same

	Threshold of collapse	few hours	up to 1 week	up to 1 day	up to 1 week	up to 1 week	up to 1 week few hours
Sustainability	*Critical functions ("s." for "supply", "p." for "production")*	clean water s. clean air s. food p.	clean air s. clean water s. food p.	clean water s. clean air supply food p.	clean water s. food p. clean air s.	food p. clean water s. clean air s.	clean water s. food p. clean air s.
	Threshold of recovery	5 years	5 years	5 years	5 years	5 years	5 years
	Quality after recovery	better	better	better	better	better	better
	Threshold of collapse	none	none	none	none	none	until you can compensate for them

When considering the cumulative responses per each municipality, the perceived levels of resilience and of sustainability result homogeneous throughout the case studies. Indeed, the most common assessment identified a medium level of resilience (MR) and a medium level of sustainability (MS), regardless of the municipality. Similarly, some common trends might be evidenced through the examination of the other investigated pivotal factors, both for resilience (Fig. 13.7) and sustainability (Fig. 13.8).

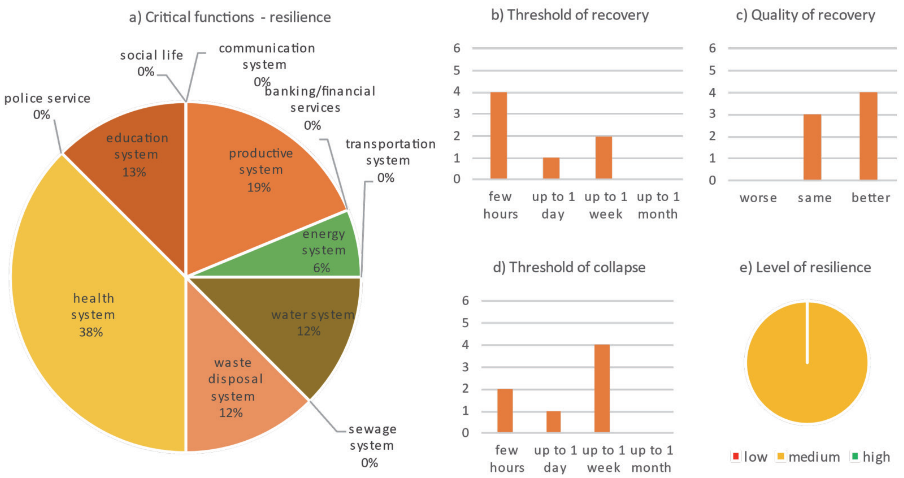


Fig. 13.7 - Most common preferences in terms of critical functions (a), threshold (b) and quality (c) of recovery, threshold of collapse (d) and level (e) of sustainability throughout the surveyed municipalities

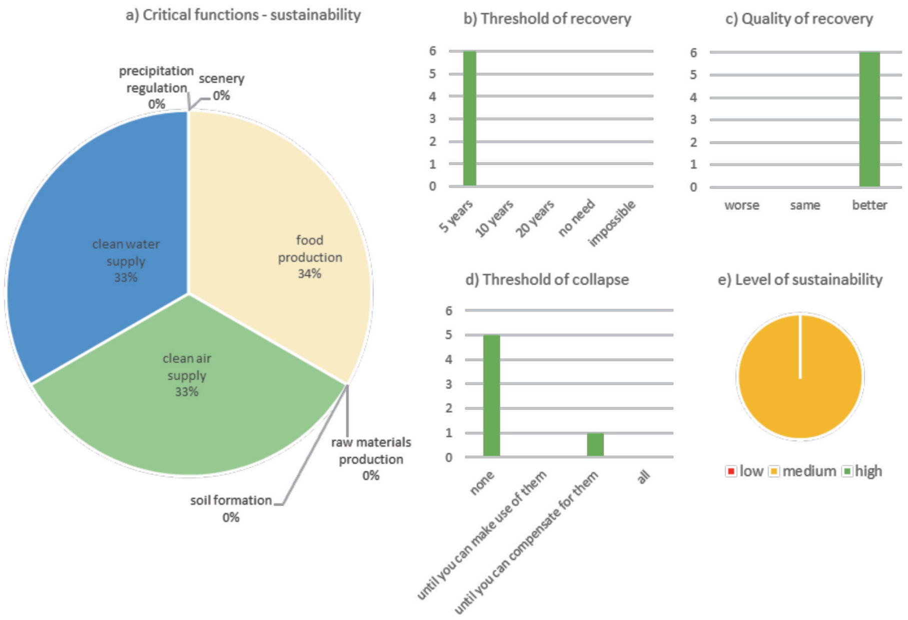


Fig. 13.8 - Most common preferences in terms of critical functions (a), threshold (b) and quality (c) of recovery, threshold of collapse (d) and level (e) of resilience throughout the surveyed municipalities

In terms of critical functions, when referring to disaster resilience the highest preferences were shared among the health system (38%), productive system (19%) and education system (13%), although some other functions emerged as significantly valued. Conversely, when considering environmental sustainability responses distinctly and equally preferred three critical functions: food production, clean air supply and clean water supply. In a similar vein, the responses in terms of threshold (of recovery and of collapse) were rather distributed among the available options for the *resilience core*, whereas they were strictly focused for the *sustainability core*. Nevertheless, the majority of the responses recognised the shortest periods of time (few hours or 5 years) as most desirable for both thresholds and both *cores*, except for the collapse of the resilience-related functions, whose loss could be generally tolerated for a longer time (up to 1 week). The preferences for the desired (or expected) quality of the critical functions after their recovery pointed at the same as before if not better for resilience, while only at an improved conditions for the sustainability.

At this point it might be significant to delve into the possible differences among municipalities. This might especially interesting when the perceived level was consistently the medium one, across both resilience and sustainability, and the surveyed municipalities. Notably, such perceived level, that was discussed up to this point, refers to the average perception per municipality. Consequently, it might be interesting to focus on the perceived level resulting per each question (thus before the average was calculated) per each municipality.

Indeed, the response to some themes appear to contrast the overall trend. That was the case for five questions concerning disaster resilience and four related to environmental sustainability (Fig. 13.9).

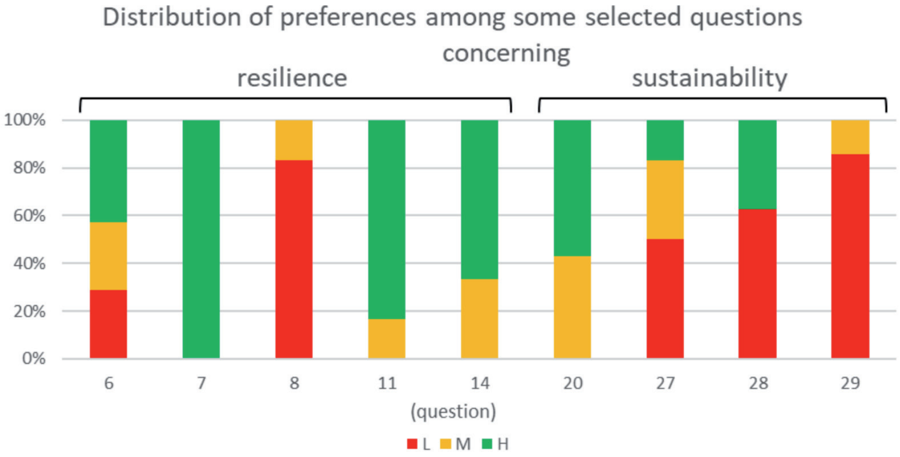


Fig. 13.9 - Distribution of preferences among some selected questions (n) per each level (low - L, medium - M, high - H) and per each core (resilience and sustainability)

In particular, questions 6 ("*my fellow citizens have become more aware of flood risk*") and 27 ("*effects of human activities on river and streams*") presented the most distributed response over all the available options. Questions 11 ("*amount of damage*"), 14 ("*return to everyday life*") and 20 ("*land use change (natural and cultivated areas in urban and industrial areas)*") exhibited a preference over the medium-high levels, with a sensible inclination towards the highest end. Questions 8 ("*the citizens of my municipality have enough means and sources to manage a flood emergency*") and 29 ("*initiatives to reduce (water, air, soil) pollution*") tended over the medium-low levels, with an evident preference of the extreme end of the interval. On the contrary, question 28 ("*protection of natural areas*") distributed the preference between the lowest and highest extreme, with a predominance of the low level. Lastly, for question 7 ("*I have become more* *aware of flood risk*") all responses converged to the highest level. In a few words, questions 6 and 27 were related to the most divisive topics, being the consequences of a flood event and the direct consequences of anthropic activities. Conversely, the remaining questions tended to polarise the preferences of the respondents towards the (perceived) extreme levels of resilience and of sustainability.

13.3. Analysis of the individual response

The previous analysis focused on the perceived level of resilience and of sustainability as the result of the most frequent preferences expressed by the respondents per each municipality. Nonetheless, considering the overall homogenous outcome of the previous investigation, it might be relevant to explore how each respondent approached the proposed themes, regardless of the related municipality. Notably, in some cases a respondent provided the same frequency of preferences to two distinct (decoded) levels, hence they were associated to either a level of resilience or of sustainability, and to no combined level. They appear in the presented results labelled as "[NO]".

13.3.1. *Distribution of the perceived levels*

The first aspect that is significant to investigate is the frequency of preferences per each level, of resilience, sustainability and combined (Fig. 13.10 and Fig. 13.11).

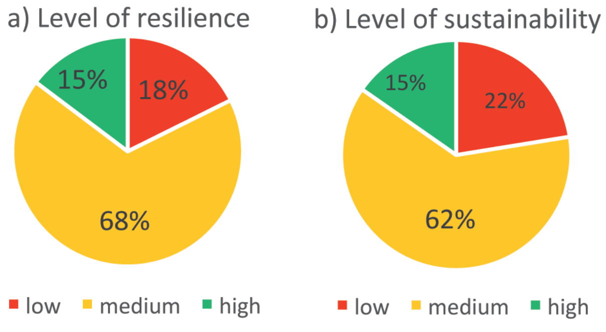


Fig. 13.10 - Distribution of the respondents among the perceived levels (low L, medium M, high H) of resilience (R) (a) and of sustainability (S) (b)

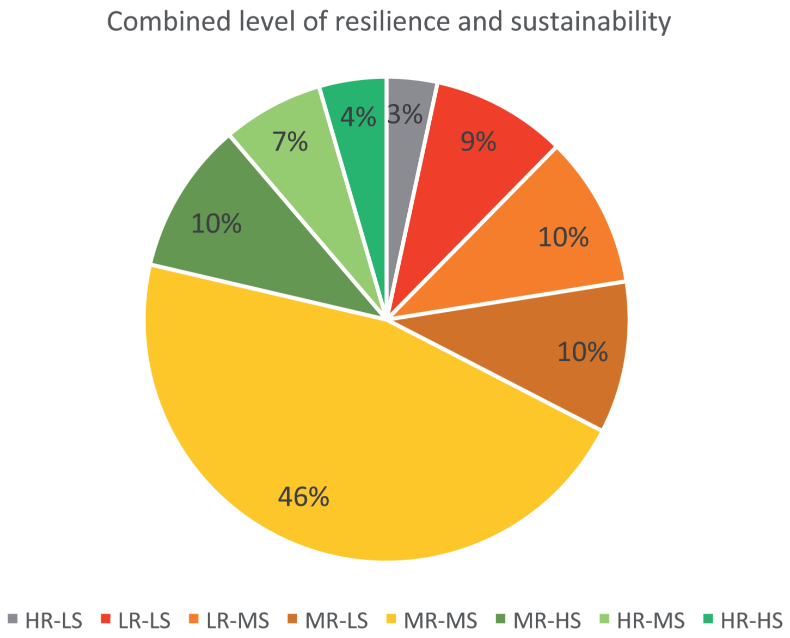


Fig. 13.11 - Distribution of the respondents among the combined perceived levels (low L, medium M, high H) of resilience (R) and sustainability (S)

For both *cores*, the most frequent level was the medium one (MR 68%, and MS 62%), whereas the extremes shared almost equally the remaining preferences, with a slight prevalence of the lower levels (LR 18%, LS 22%). In terms of combination, the association of the medium levels retains the wider preference (MR-MS 46%), followed by the combinations of the medium with the lower levels (of both *cores*) or with the highest level of sustainability (LR-MS 10%, MR-LS 10%, MR-HS 10%). Among the other possibilities, the only significant one is represented by the combination of the lowest levels (LR-LS 9%).

13.3.2. *Demographic traits*

A further exploration involves the demographic characteristics of the respondents (Tab. 13.13, Tab. 13.14 and Tab. 13.15).

Tab. 13.13 - Contingency table: perceived level (low L, medium M, high H) of resilience (R) and gender

		39. Gender identified with		Total
		female	*male*	
Perceived level - resilience	*[NO]*	7	4	11
	HR	12	3	15
	LR	7	11	18
	MR	40	29	69
Total		66	47	113

Tab. 13.14 - Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and gender

		39. Gender identified with		Total
		female	*male*	
Perceived level - sustainability	*[NO]*	9	6	15
	HS	11	4	15
	LS	11	11	22
	MS	35	26	61
Total		66	47	113

Tab. 13.15 - Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and gender

		39. Gender identified with		Total
		female	*male*	
Perceived level - combined	*[NO]*	15	9	24
	HR-HS	4	0	4
	HR-LS	2	1	3
	HR-MS	5	1	6
	LR-LS	2	6	8
	LR-MS	4	5	9
	MR-HS	4	5	9
	MR-LS	7	2	9
	MR-MS	23	18	41
Total		66	47	113

Overall, the highest levels (of resilience, sustainability and combined) were generally associated to a majority of female respondents. The combination of the most desirable levels (HR-HS) was an extreme exemplification, with all preferences due to female respondents. The other levels provided a more scattered response. Nevertheless, the lowest level of sustainability (LS) was the only case of same number of preferences between female and male respondents, whereas the least desired combined level (LR-LS) was mainly associated to male respondents.

When considering the age distribution throughout the levels, it emerges a significant predominance of the highest classes in all the considered levels (Tab. 13.16, Tab. 13.17 and Tab. 13.18).

Tab. 13.16 - Contingency table: perceived level (low L, medium M, high H) of resilience (R) and age

			40. Class of age							
			18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
Perceived level - resilience	*[NO]*	0	1	1	0	3	3	2	1	11
	HR	0	0	1	0	1	8	4	1	15
	LR	0	2	1	3	6	4	1	1	18
	MR	2	8	11	4	10	11	21	2	69
Total		2	11	14	7	20	26	28	5	113

Tab. 13.17 - Contingency table: perceived level (low L, medium M, high H) and of sustainability (S) and age

			40. Class of age							
			18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
Perceived level - sustainability	*[NO]*	1	3	4	0	2	4	1	0	15
	HS	0	0	0	0	1	4	7	3	15
	LS	0	1	1	1	5	8	6	0	22
	MS	1	7	9	6	12	10	14	2	61
Total		2	11	14	7	20	26	28	5	113

Tab. 13.18 - Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and age

			40. Class of age							
			18-24 years old	*25-34 years old*	*35-44 years old*	*45-54 years old*	*55-64 years old*	*65-80 years old*	*over 80 years old*	*Total*
Perceived level - combined	*[NO]*	1	4	4	0	5	6	3	1	24
	HR-HS	0	0	0	0	0	3	0	1	4
	HR-LS	0	0	0	0	0	1	2	0	3
	HR-MS	0	0	1	0	1	3	1	0	6
	LR-LS	0	0	0	0	5	3	0	0	8
	LR-MS	0	2	0	3	1	1	1	1	9
	MR-HS	0	0	0	0	0	1	7	1	9
	MR-LS	0	1	1	1	0	3	3	0	9
	MR-MS	1	4	8	3	8	5	11	1	41
Total		2	11	14	7	20	26	28	5	113

When considering the extreme levels (high and low), the resilience case appeared to be preferred by the younger class compared to the sustainability level (e.g. HR was preferred by 55-64 years old respondents, whereas HS by 65-80 years old respondents). The medium levels were mainly associated to the same class of age (65-80 years old). In general terms, when combining the same level of the two *cores* (HR-HS, MR-MS, LR-LS), the dominant class of age corresponded to that of the resilience side. Notably, only the LR-MS envisioned a significant contribution of the youngest class (18-24 years old), whereas MR-MS included the following class (25-34 years old).

The characterisation of the respondents per each option in terms of education appeared overall homogeneous (Tab. 13.19, Tab. 13.20 and Tab. 13.21).

Regardless of the *core* or of the combination, each level was dominated by the high-school option, equalled by the Master's degree (or equivalent) option in the case of the highest levels (HR and HS). Notably, the Master's degree (or equivalent) option was the most present both for the most desirable (HR-HS) and for the intermediate (MR-MS) combined level.

Tab. 13.19 - Contingency table: perceived level (low L, medium M, high H) of resilience (R) and education

		41. Highest level of education							
			Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	*Total*
Perceived level - resilience	*[NO]*	0	3	0	0	2	0	6	11
	HR	0	5	2	1	0	2	5	15
	LR	1	3	1	1	0	4	8	18
	MR	3	17	6	4	6	9	24	69
Total		4	28	9	6	8	15	43	113

Tab. 13.20 - Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and education

		41. Highest level of education							
			Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	*Total*
Perceived level - resilience	*[NO]*	0	3	0	0	2	0	6	11
	HR	0	5	2	1	0	2	5	15
	LR	1	3	1	1	0	4	8	18
	MR	3	17	6	4	6	9	24	69
Total		4	28	9	6	8	15	43	113

Tab. 13.21 - Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and education

		41. Highest level of education							
			Master's degree or equivalent	*Bachelor's degree or equivalent*	*doctoral degree or equivalent*	*elementary school*	*middle school*	*high school*	*Total*
Perceived level - combined	*[NO]*	1	7	1	1	2	1	11	24
	HR-HS	0	2	0	1	0	1	0	4
	HR-LS	0	1	0	0	0	0	2	3
	HR-MS	0	1	2	0	0	1	2	6
	LR-LS	0	1	0	1	0	2	4	8
	LR-MS	1	1	1	0	0	2	4	9
	MR-HS	1	1	0	0	2	1	4	9
	MR-LS	0	2	0	0	0	2	5	9
	MR-MS	1	12	5	3	4	5	11	41
Total		4	28	9	6	8	15	43	113

The overall economic conditions of the respondents were rather similar throughout the levels, with highest frequencies in the first two classes (0-15000€ and 15001-30000€) (Tab. 13.22, Tab. 13.23 and Tab. 13.24).

Tab. 13.22 - Contingency table: perceived level (low L, medium M, high H) of resilience (R) and income

		49. Class of income					Total
			0 - 15000€	15001 - 30000€	30001 - 50000€	more than 50000€	
Perceived level - resilience	[NO]	1	2	8	0	0	11
	HR	2	6	5	2	0	15
	LR	1	4	8	4	1	18
	MR	10	21	24	10	4	69
Total		14	33	45	16	5	113

Tab. 13.23 - Contingency table: perceived level (low L, medium M, high H) of sustainability (S) and income

		49. Class of income					Total
			0 - 15000€	15001 - 30000€	30001 - 50000€	more than 50000€	
Perceived level - sustainability	[NO]	2	4	7	2	0	15
	HS	5	3	6	1	0	15
	LS	1	4	11	6	0	22
	MS	6	22	21	7	5	61
Total		14	33	45	16	5	113

Tab. 13.24 - Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and income

		49. Class of income					Total
			0 - 15000€	15001 - 30000€	30001 - 50000€	more than 50000€	
Perceived level - combined	[NO]	3	5	14	2	0	24
	HR-HS	1	2	1	0	0	4
	HR-LS	0	0	2	1	0	3
	HR-MS	0	4	2	0	0	6
	LR-LS	0	0	5	3	0	8
	LR-MS	1	3	3	1	1	9
	MR-HS	4	1	3	1	0	9
	MR-LS	0	4	3	2	0	9
	MR-MS	5	14	12	6	4	41
Total		14	33	45	16	5	113

Notably, the 15001-30000€ class resulted largely dominant compared to the others in the cases of the lower levels of the *cores* and of their combination (LR, LS, LR-LS). Conversely, all the respondents belonging to the highest class (more than 50000€) were related to medium levels, of resilience and of sustainability, and most of them to their combination (MR-MS).

Regardless of the level, the absolute majority of the respondents were associated to the longest period of residence (more than 10 years) in their municipality (Tab. 13.25, Tab. 13.26 and Tab. 13.27).

Tab. 13.25 - Contingency table: perceived level (low L, medium M, high H) of resilience (R) and residence

		43. Permanence in municipality of residence					*Total*
			1 year or less	*2-5 years*	*5-10 years*	*more than 10 years*	
Perceived level - resilience	*[NO]*	0	0	0	0	11	11
	HR	0	0	0	0	15	15
	LR	1	0	0	0	17	18
	MR	3	2	1	2	61	69
Total		4	2	1	2	104	113

Tab. 13.26 - Contingency table: perceived level (low L, medium M, high H) and of sustainability (S) and residence

		43. Permanence in municipality of residence					*Total*
			1 year or less	*2-5 years*	*5-10 years*	*more than 10 years*	
Perceived level - sustainability	*[NO]*	1	0	0	0	14	15
	HS	1	0	0	0	14	15
	LS	0	1	0	0	21	22
	MS	2	1	1	2	55	61
Total		4	2	1	2	104	113

Tab. 13.27 - Contingency table: perceived combined level (low L, medium M, high H) of resilience (R) and of sustainability (S) and residence

		43. Permanence in municipality of residence					*Total*
			1 year or less	*2-5 years*	*5-10 years*	*more than 10 years*	
Perceived level - combined	*[NO]*	1	0	0	0	23	24
	HR-HS	0	0	0	0	4	4
	HR-LS	0	0	0	0	3	3
	HR-MS	0	0	0	0	6	6
	LR-LS	0	0	0	0	8	8
	LR-MS	1	0	0	0	8	9
	MR-HS	1	0	0	0	8	9
	MR-LS	0	1	0	0	8	9
	MR-MS	1	1	1	2	36	41
Total		4	2	1	2	104	113

The medium levels (of resilience and of sustainability) presented the widest variability, with respondents pertaining to all the available periods, and accordingly did the combined intermediate levels (MR-MS). Interestingly, when a high level was concerned (either of a *core* or combined), the respondents resulted to have spent the longest period of time in their municipality.

13.3.3. *Assessed vs. perceived levels*

A further investigation associated the assessed levels (different for each municipality) and the perceived levels (among the respondents of each municipality). This allowed to explore which was the most frequently perceived level per each assessed level (Tab. 13.28, Tab. 13.29 and Tab. 13.30). Indeed, given that each assessed level corresponds to a municipality, the question might be simplified as: "Within a specific (assessed) level, which is the most common perception of the respondents?".

Tab. 13.28 - Contingency table: perceived and assessed level (low L, medium M, high H) of resilience (R)

		Assessed level						*Total*
		MR-MS	*MR-LS*	*LR-MS*	*HR-HS*	*MR-HS*	*HR-MS*	
Perceived level - resilience	*[NO]*	3	2	2	1	1	2	11
	HR	5	2	3	1	2	2	15
	LR	3	7	2	4	1	1	18
	MR	8	11	6	20	13	11	69
Total		19	22	13	26	17	16	113

Tab. 13.29 - Contingency table: perceived and assessed level (low L, medium M, high H) of sustainability (S)

		Assessed level						*Total*
		MR-MS	*MR-LS*	*LR-MS*	*HR-HS*	*MR-HS*	*HR-MS*	
Perceived level - sustainability	*[NO]*	1	4	2	2	3	3	15
	HS	4	2	1	2	2	4	15
	LS	7	5	3	3	3	1	22
	MS	7	11	7	19	9	8	61
Total		19	22	13	26	17	16	113

Tab. 13.30 - Contingency table: perceived combined and assessed level (low L, medium M, high H) of resilience (R) and of sustainability (S)

		Assessed level						*Total*
		MR-MS	*MR-LS*	*LR-MS*	*HR-HS*	*MR-HS*	*HR-MS*	
Perceived level - combined	*[NO]*	4	5	4	3	4	4	24
	HR-HS	3	0	0	0	0	1	4
	HR-LS	1	1	1	0	0	0	3
	HR-MS	1	0	1	1	2	1	6
	LR-LS	2	3	2	1	0	0	8
	LR-MS	0	4	0	3	1	1	9
	MR-HS	1	1	0	2	3	2	9
	MR-LS	3	1	0	2	2	1	9
	MR-MS	4	7	5	14	5	6	41
Total		19	22	13	26	17	16	113

The majority (27.3%) of the respondents perceiving a high level of resilience (HR) belonged to a municipality assessed in combined intermediate conditions (MR-MS), whereas the majority (26.7%) of the respondents perceiving a high level of sustainability (HS) belonged to a municipality assessed in at least combined intermediate conditions (MR-MS and HR-MS). Considering the lowest perceived levels (LR and LS), in terms of resilience respondents most frequently (38.9%) belonged to the MR-LS municipality, while in terms of sustainability to the MR-MS municipality (31.8%). Lastly, respondents associated to a medium level, either of resilience (MR) or of sustainability (MS), most frequently (29.0% and 31.1%, respectively) belonged to the municipality in the most desirable conditions (HR-HS). It is noteworthy that these values are not affected by the widespread preference over the medium levels, since the percentages are valid within each perceived level.

The comparison among perceived and assessed combined levels returns a rather multifaceted picture. Some discrepancies emerged evidently, as some respondents were associated to perceived levels (HR-LS and LR-LS) that were not previously assessed. It might be noteworthy that within the perceived LR-LS level, the respondents were distributed among four assessed levels (MR-MS, MR-LS, LR-MS and HR-HS), with the majority (37.5%) belonging to the MR-LS municipality. Conversely, among the respondents who perceived the most desirable conditions (HR-HS), none of them belonged to the HR-HS municipality, rather being distributed between the MR-MS and the HR-MS municipalities. Turning to the intermediate perceived conditions (MR-MS), which was also the most common preference in general terms, the majority (34.1%) belonged to the most performing municipality (HR-HS).

Lastly, it might be significant to explore the distribution of combined levels within an assessed level. In the HR-HS municipality, most of the respondents (53.8%) perceived an intermediate condition (MR-MS), while within the assessed MR-MS municipality, apart from the majority (21.1%) perceiving the corresponding combined level, a significant portion of respondents was distributed between the HR-HS and MR-LS levels (15.8% each).

13.3.4. *Perceived levels and key indicators*

As mentioned above, the questionnaire included themes that echoed the indicators employed in the first phase of the quantitative analysis. This allowed not only to derive the perceived levels of resilience and of sustainability, but also to compare such perceived levels and the indicators resembling those used in the quantitative assessment (Tab. 13.31 and Tab. 13.32). In this case, the outcome will consider only the individually perceived levels, in order to ease the interpretation of the results. In addition, values will be presented in terms of highest frequency.

Tab. 13.31 - Perceived level (low L, medium M, high H) of resilience (R) and key indicators: most frequently preferred option and related metrics

			9. Population growth in flooding areas	*11. Amount of damage after flood*	*10. Economic welfare after flood*
Perceived level – resilience	*[NO]*	*option*	*as usual*	*low*	*as usual*
		count	6	6	8
	HR	*option*	*as usual*	*low*	*as usual*
		count	9	7	12
	LR	*option*	*as usual*	*high*	*worse*
		count	9	7	12
	MR	*option*	*as usual*	*low*	*as usual*
		count	51	33	52

Tab. 13.32 - Perceived level (low L, medium M, high H) of sustainability (S) and key indicators: most frequently preferred option and related metrics

			19. Transformation of green areas	*21. Quantity of urban and industrial use of water*	*26. Number of species in dangerous conditions*
Perceived level - sustainability	*[NO]*	*option*	*as usual*	*lower/higher*	*average*
		count	8	5/5	7
	HS	*option*	*wider*	*as usual/higher*	*average*
		count	9	6/6	7
	LS	*option*	*smaller*	*as usual/higher*	*high*
		count	10	8/8	8
	MS	*option*	*as usual*	*as usual*	*average*
		count	50	45	40

In general terms, the preferences of the respondents associated to the highest levels (HR and HS) often resembled those of the respondents related to medium levels (MR and MS), regardless of the considered indicator. In these cases, the respondents favoured the options related to intermediate judgements ("as usual", "average"). The respondents associated to the lowest levels (LR and LS) most frequently preferred the options representing extremes ("high", "worse", "smaller", "higher"), except for the high level of sustainability (HS) when addressing the transformation of green areas (the most preferred option was "wider"). The indicator dealing with population growth received the most homogenous response, as in every case the most preferred option was "as usual", and similarly a significant portion of respondents, throughout the perceived levels of sustainability, selected the option "as usual" when asked about the quantity of water employed for human activities. Notably, the topic of sustainability was sometimes divisive. Indeed, while in all other cases a distinct preference clearly emerged, for one of the sustainability-related indicators (water use for human activities) the respondents were equally distributed among two of the available options ("as usual" and "higher"), although this ambiguity did not involve the respondents associated to MS.

In analogy to the quantitative analysis, at this point it is possible to draw the configuration of the clusters of resilience and of sustainability based on the perception of the respondents (Fig. 13.12 and Fig. 13.13). In other words, the most preferred option per each key indicator suggests the definition of the levels of resilience and of sustainability.

To begin with, it might be interesting to observe that in the resilience case, the highest and medium levels/clusters (HR and MR) exhibit the same trends in terms of preferences, whereas in the sustainability case the high and low levels/clusters (HS and LS) confirm the ambiguity in the identification of the most common preference between the indicators, as anticipated above. In addition, for the *resilience core*, the high (HR) and medium (MR) levels are perceived as characterised by an invariance in the presence of population in flooding areas, a low amount of damage suffered after a flood event and a general invariance in the local economic welfare. Nevertheless, the entity of preference of the intermediate conditions (that is, the invariance) was more stable for the MR, with overall higher percentages throughout the indicators, while in terms of the economic welfarethe percentage was higher for the respondents associated to the HR. The low level of resilience (LR) was depicted as an invariance of the exposed population to flood, a high magnitude of suffered damages and a decrease in the economic welfare of the community. When turning to the *sustainability core*, the high level of sustainability (HS) was represented as a

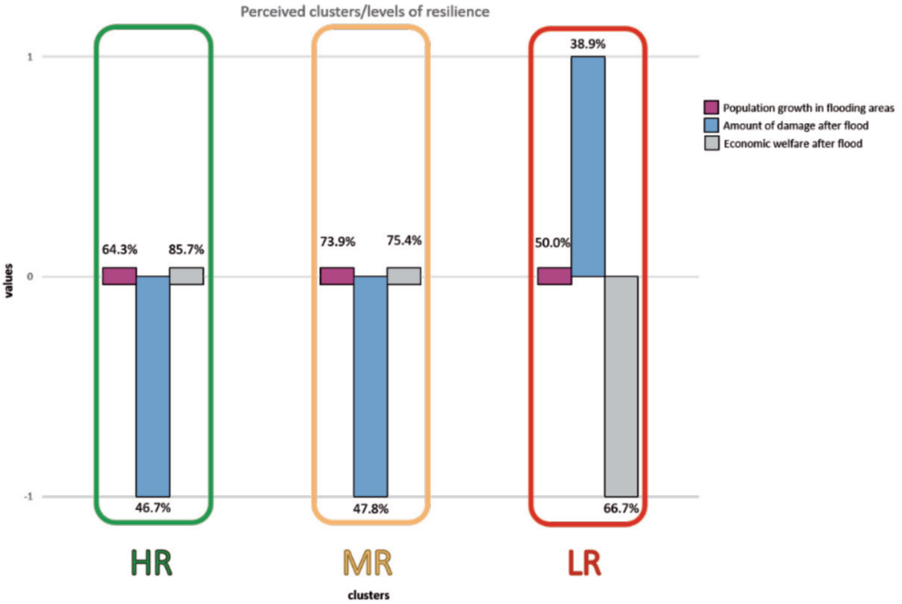


Fig. 13.12 - Perceived levels of resilience (low - LR, medium - MR, high - HR) and the most preferred option (with related percentage) for key indicators of the questionnaire

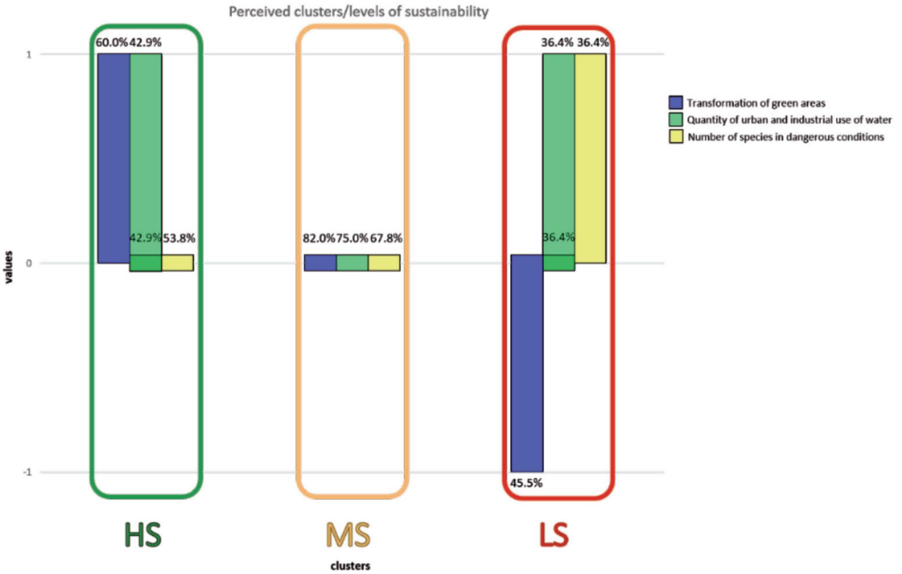


Fig. 13.13 - Perceived levels of sustainability (low - LS, medium - MS, high - HS) and the most preferred option (with related percentage) for key indicators of the questionnaire

condition where green areas are expanding, the quantity of anthropic water use is unvaried/increasing and the number of species in inadequate preservation conditions are on an average level. The medium level (MS) appears perceived as a general invariance of all indicators. Lastly, the low level (LS) is represented by a decreased extension of green areas, a usual/higher quantity of water employed for human activities and a high number of species in dangerous conditions.

13.3.5. *Assessed levels and key indicators*

Notably, each surveyed municipality was associated to a combined assessed level of resilience and sustainability. It follows that it was also possible to intersect such combined assessed levels and previously mentioned key indicators (Tab. 13.33 and Tab. 13.34). In other words, the previous outcomes provide insights on the perception of the transformations of the municipality, related to the perceived condition of resilience and of sustainability. The outcomes that are going to be introduced here aim at exploring the perception of the transformations of the municipality, related to the assessed condition of resilience and sustainability. Consequently, only the dominant preferences will be presented here.

In general terms the intermediate options ("as usual", "average") were preferred, regardless of the related municipality. In other words, independently of residing in more or less desirable conditions, the perceived transformation was an invariance of the *status quo* (thus corresponding to the options decoded as representing medium levels of resilience or of sustainability). Some exceptions were identified for the LR-MS municipality, whose

Tab. 13.33 - Assessed level (low L, medium M, high H) of resilience (R) and key indicators of resilience: most frequently preferred option and related metrics

			9. Population growth in flooding areas	*11. Amount of damage after flood*	*10. Economic welfare after flood*
Assessed level	*MR-MS*	*option*	*as usual*	*low*	*as usual*
		count	11	13	10
	MR-LS	*option*	*as usual*	*low*	*as usual*
		count	14	9	13
	LR-MS	*option*	*as usual/less people*	*not high not low*	*as usual*
		count	6/6	6	12
	HR-HS	*option*	*as usual*	*low*	*as usual*
		count	15	11	15
	MR-HS	*option*	*as usual*	*low*	*as usual*
		count	15	9	13
	HR-MS	*option*	*as usual*	*low*	*as usual*
		count	14	7	15

Tab. 13.34 - Assessed level (low L, medium M, high H) of sustainability (S) and key indicators of sustainability: most frequently preferred option and related metrics

			19. Transformation of green areas	21. Quantity of urban and industrial use of water	26. Number of species in dangerous conditions
Assessed level	MR-MS	option	as usual	as usual	average
		count	9	9	10
	MR-LS	option	as usual	as usual	average
		count	15	13	9
	LR-MS	option	as usual	as usual	low/average
		count	10	7	6/6
	HR-HS	option	as usual	as usual	average
		count	16	17	18
	MR-HS	option	as usual	as usual	low/average
		count	12	8	7/7
	HR-MS	option	as usual	as usual	average
		count	8	9	11

respondents exhibited an ambiguity of preference when dealing with the variation of the population exposed to flood hazard and with the number of species in inadequate conditions. In the latter case, also the MR-HS municipality provided an uncertain outcome. Nevertheless, it is noteworthy that in these cases the ambiguity revolved around the medium/low options, that related to medium/high levels of resilience or of sustainability (e.g. as previously mentioned, "less people" related to exposed population was interpreted as a perception of high resilience; similarly, "low" related to the number of endangered species was considered as a perceived high level of sustainability).

13.3.6. *Perceived levels and other related themes*

Some closing considerations explore the general relation among the perceived levels and the proposed questions. Although the questions echoing the indicators of the previous cluster analysis carried a specific meaning for the investigation, all the questions concurred in delineating the resilience and sustainability level of the municipalities, as perceived by the respondents. Consequently, it might be significant to consider whether some topics allowed the emergence of specific traits. This might be especially significant, considering the methodology adopted to decode the expressed preferences in perceived levels (of resilience and of sustainability). Indeed, such methodology prioritized major trends, thus possibly obscuring some minor yet detectable issues.

The response to the questions that directly addressed perceived behaviour, on different scales, was distinctive. When asked whether they perceived themselves more aware of flood risk ("*7. I have become more aware of flood risk*") all the respondents agreed on a positive reply, regardless of the *core* considered (that is, all respondents, for all levels of resilience and of sustainability converged towards this self-perception). Nevertheless, such solid picture would be promptly questioned by the complementary question directed towards the other residents of their municipality ("*6. my fellow citizens have become more aware of flood risk*"), where preferences were distributed among the available options, generally matching the corresponding level. The third question in this thematic cluster ("*8. the citizens of my municipality have enough means and sources to manage a flood emergency*") allowed to evidence a unusual perception of low resilience among respondents corresponding to the overall MR and MS levels.

The parallel thematic set concerned the efficacy of flood emergency management, considered at different scales: local authorities, fellow citizens and personal (questions *16* to *18*). In this case, the picture matched the expectations, with preferences attributed to the option corresponding to the perceived level of the respondent. Nonetheless, an exception could be still observed: respondents identified with a high level of sustainability showed a significant uncertainty over the increased ability of their fellow citizens to face a flood emergency ("*17. my fellow citizens have become able to effectively manage a flood emergency*"), that was decoded as a medium perceived level (of resilience).

A further unusual behaviour was observed when considering the last issues of the sustainability section of the questionnaire, being the protection of natural areas and the mitigation of anthropic pollution (questions *28* and *29*). While the association among sustainability levels and preferred options tended to be highly consistent with the expected preferred options, the resilience levels did not agree with such picture. Indeed, the perception about the protection of natural areas ("*28. protection of natural areas*") envisioned mild judgements coming from some HS respondents along with the majority of the LR respondents, whereas the MR respondents tended to favour the most encouraging option. In contrast, the discussion over the efforts to mitigate polluting emissions ("*29. initiatives to reduce (water, air, soil) pollution*") registered a unanimous convergence towards a general disapproval and discouragement of the enacted activities.

Lastly, it is noteworthy that when considering the anthropic impact on the riverine area ("*27. effects of human activities on river and streams*"), the respondents were again polarised around the most severe judgement, that is recognising a general negative effect of humans on the natural water system.

14. Discussion

The previous chapters explored the expansion of the overall methodology. In particular, the process investigated the perceived level of disaster resilience and environmental sustainability of the municipalities by means of questionnaires delivered to the local communities. The survey involved six case studies of the Marche region, each representing a combined level of resilience and sustainability as previously quantitatively assessed.

In the following paragraphs the discussion of the observed outcomes will proceed similarly to the previous section, that is through the characterisation of the overall judgement of each municipality, then considering the views of the individual respondents and eventually leading to some insights on the local capacities.

14.1. General perception of the resilience and sustainability level

As previously mentioned, the municipalities were selected in order to satisfy two main criteria: *i.* being representative of one of the combined resilience and sustainability levels identified in the previous analytical process, with the aim of comparing the assessed levels with the perceived ones; *ii.* belonging to the same river basin, in this case the Esino river basin, so that the physical, social and cultural characteristics would be representative of a such physiographic unit, to allow a comparison among the responses.

The collected questionnaires received similar percentages of response among the municipalities, ranging from 13 to 26 forms. Indeed, the response mirrored the magnitude of the population, thus it was reasonable to receive more answers from municipalities such as Jesi, Falconara Marittima and Fabriano. As the survey was mostly carried on through telephone contacts, the willingness to participate in the research resulted a significant factor for the collection of the local perceptions. As a consequence, it might be interesting to analyse the responding population. In general terms, the emerging profile of the respondent is a female, aged between 45 and 80 years old (more probably between 65-80 years old), who completed high school, whose income is around 15001-30000€ and has spent most of her life in her municipality. In other words, when dialling a random number, this kind of answering profile would most probably agree to take part in the survey and thence to provide their view on the local capacities to deal with flood risk and to manage environmental issues. It might be also assumed that this answering profile would be the most actively interested in disclosing personal beliefs and ideas, as well as the most engaged and aware of the topics proposed through the questionnaire.

Notably, though the methodological design intended to emphasise the local features of the municipalities (significantly differing for resilience and sustainable capacities), the local perceptions were largely homogeneous. That is, the respondents of all six municipalities converged towards a common assessment of medium resilience and sustainability capacities. As a consequence, MR-MS resulted the perceived combined level for all case studies. This might suggest that, regardless of the efforts (or inactivity) of the municipalities to foster resilience and sustainability, the population would be generally cautious in their judgements, avoiding extreme statements. Although this might be due to a personal, yet generalised, attitude of not revealing radical beliefs, rather exhibiting a moderate approach, such a uniform response might still be informative of the overall perception of the local communities. In particular, it might be reasonable to extend such generalisation at least to the Esino river basin, if not to the whole Marche region. Indeed, as previously mentioned, the river catchment presents similar features within its borders, but it is also consolidated that the characteristics of the Marche region are rather comparable throughout the area. The first consequence of such generalised moderate approach is that the perceived level does not match the assessed level of resilience and sustainability. It might be argued that this is due to the quantitative analysis missing some important traits, conversely recognised by local communities. Nevertheless, also in light of the comparative methodology of the previous phases, it appears hardly possible that all municipalities actually belonged to the MR-MS level. Consequently, such a mismatch might reasonably be considered significant. It suggests that the higher efforts towards the strengthening of resilience and sustainability capacities were not evident for the local communities or that the effects of such endeavours did not reach the population. At the same time, it might also translate in unfounded confidence in local capacities. Such a condition might be especially concerning in case of a disaster, as for instance assuming that the community owns capacities more consistent than they reasonably are may result in an inadequate behaviour compared to the actual risk. These considerations suggest that the identification of such mismatches might be especially informative when planning the dissemination of the achieved results or when accounting for the local attitudes in specific situations.

The questionnaire also aimed at enabling the local communities to indicate which are the assets that they value the most, along with the related acceptability of loss and recovery. These aspects are especially relevant within the context of the panarchy paradigm, which served as the basis of the present research endeavour. Indeed, the development and especially the collapse of an *adaptive cycle* is defined by the status of the basic, identifying functions of the system. As a consequence, it is fundamental first, to identify such basic functions and second, to define the thresholds of their loss and of their restoration. In this context, a substantial difference between the *resilience* and the *sustainability cores* could be identified. Such difference emerges since a preliminary examination of the overall picture: while the preferences expressed for the themes related to resilience show a considerable variation among the respondents, the case of the sustainability-related topics reaffirmed a general homogeneity of the responses. Hence, it appears that while the matters concerning anthropic processes and their preservation might spark discussion and division among the population (at least on a physiographic or regional level), the same does not occur for issues related to the environment. In brief, it appears that generally the preservation of the environment is perceived as a pivotal topic. More in detail, the most valued functions in terms of resilience capacities were the health system, the productive system and the education system, followed by the waste management, the water and energy systems. It is acknowledged that the relevance attributed to these assets, and especially to the health system, might be affected by the occurred extraordinary conditions (the questionnaires were delivered during the COVID-19 pandemic, causing a potential bias and possibility altering viewpoints). Nonetheless, the expressed preferences portrait communities that prioritise work and education over other commodities. It appears that the surveyed communities recognise the highest importance to the preservation of the activities that define the individual role and contribution to society, as well as that allow personal self-sufficiency, along with the welfare system that characterise the Italian national health management. However, the communities exhibit a different tolerance of their loss: though the majority could withstand a rather long period (up to one week) before feeling affected, some communities affirm that would be able to bear only few hours without such basic functions. After a loss actually occurs, though the majority expects them to be recovered in the least time possible, some might accept to wait for more time. Notably, such differences are not associated to the levels of resilience, as for instance higher levels of resilience do not necessarily correspond to a higher tolerance of the potential interruption of such functions. Indeed, respondents related to the municipality of Jesi (HR-HS) would tolerate an interruption of one week and a recovery process of few hours, whereas the respondents from Serra San Quirico (HR-MS) would accept both an interruption and a restoration lasting up to one week; nevertheless, the case of Jesi is mirrored by the cases of Falconara Marittima (MR-LS) and of San Marcello (MR-HS), both identified with a lower level of resilience. It is noteworthy that the least performing municipality (that is Genga, LR-MS) exhibits a high tolerance both of loss (up to one day) and recovery (up to one week). Such an inhomogeneity suggests that rather than the quantitatively assessed level of resilience, other factors might be governing the level of acceptability of the potential impact of a disaster. Notably, all the municipalities were associated to a perceived medium level of resilience, thus not providing a decisive factor. In this case local characteristics and dynamics might become especially significant. The aspect of resilience-related themes that allowed to identify two distinct groups among the municipalities concerned the expectations towards the quality of the recovered functions. While the municipalities associated to a combined level including at least one high extreme (Jesi HR-HS, San Marcello MR-HS, Serra San Quirico HR-MS) would accept the maintenance of the same level of functionality, those in medium-low conditions (Fabriano MR-MS, Falconara Marittima MR-LS, Genga LR-MS) would prefer an increase of the local capacities. Hence, ti might be argued that the quantitatively assessed level of resilience appears indeed related to local attitudes. As mentioned, environmental issues cancel any kind of differences that could be previously delineated. Indeed, the preservation of natural assets was unanimously directed towards the ecosystem services related to water, air and food, in an effort to limit as far as possible their degradation and nurture their restoration to the point that any level of loss would not be acceptable. Such an attention to environmental themes might be a result of the ongoing environmental changes that are affecting global as well as local systems, altering the familiar landscapes and thus urging a prompt reaction. This kind of attitude might manifest more evidently in those populations that are particularly bonded with their locale, as the sense of belonging might promote a sound engagement in the protection of the local system. Indeed, the communities of the Marche region generally live in close contact with the natural environment, activities (both economic and recreational) directly dealing with nature are rather common and settlements are generally rather small and circumscribed, surrounded by natural areas. Consequently, it appears reasonable that such a rural (rather than urbanised) identity of the municipalities of the Marche region might play a pivotal role in driving the expectation for a significant endeavour in preserving natural landscapes.

When considering in detail the topics that more than others evidenced unusual attitudes, the questions related to resilience perception emerged as especially insightful. In particular, the common response denoted a confidence in the personal awareness of flood-related issues that was not shared with the fellow citizens, and in general with the potential ability of the overall community to cope with a flood emergency. Consequently, it appears that locals might rather rely on personal than common means to deal with flood emergency. At the same time, the judgement on the effects of a flood event on their community was rather moderate, thus generally recognising a mild impact of these events on the local activities. Consequently, it seems that according to the collected perceptions, the recognised significant resilience of the municipality is due more to the capacities of the individual households than of the common efforts. Acknowledging this common standpoint might be significant when designing local plans to deal with flood disasters: for instance, it suggests that further efforts should give higher visibility to the local civil protection activities, or promote trust within the communities. Coming to the sustainability themes, the relevance of environmental issues appears confirmed by the general dissatisfaction in terms of enacted activities to preserve natural areas and reduce human pollution. Nevertheless, it is remarkable that the judgement over the effects of human activities on riverine systems is not unanimously negative. Indeed, positive trust in human efforts might suggest that there is a component of the local populations that believes in the ability of humans to nurture natural systems. These observations appear to draw a picture where human activities are considered at the same time highly detrimental and potentially constructive: anthropic processes might destroy natural equilibria and hamper natural ecosystems as well as contribute to their restoration and preservation. This perspective seems rather encouraging when planning environmental strategies, as it suggests that the engagement of local communities might be not only acknowledged but also required by those same communities.

14.2. Individual perception of the resilience and sustainability level

Along with the outcomes averaged at a municipal level, it might be interesting to explore the responses at an individual level, averaging the outcomes over the perceived level, of resilience, sustainability and combined.

It might be significant to begin with the distribution of the respondents among the perceived levels. It is reasonably expected that the predominance of the medium perceived levels, as resulted from the average at the municipal scale, would influence this other average. Nevertheless, the magnitude of such predominance could be explored. It is noteworthy that the other two levels, that represent the extremes of each *core*, shared a comparable response from the locals. This suggests that there is not a commonly agreed opinion on the tendency of the general status of disaster and environmental capabilities, as an either medium-high or medium-low trend could not be identified. The combined levels provide a hint on these themes. Indeed, the levels that reach the second-highest approval among the respondents represented a combination of medium and low levels (MR-LS and LR-MS), along with a preference over high sustainability (MR-HS). Furthermore, the third highest share was achieved by the combination of the lowest levels (LR-LS). Consequently, it seems that, while the management of environmental issues does not gather a common consensus among the population, the risk-related themes lead to an overall lack of confidence in the local capacities. Although this might be a symptom of a more generalised distrust in the means and abilities of the local communities (especially local authorities), it might also be influenced by specific issues occurring in the area. Hence, it might be relevant to recognise and possibly tackle the origin of such conditions.

In terms of demographic characterisation of the respondents, the trend that emerges is a predominant preference of females for the higher levels compared to male respondents, regardless of the *core* or combination considered. Indeed, the female preference was more significant for the higher levels, progressively decreasing towards the lower levels, up to an equal distribution for the case of sustainability (LS), while the opposite occurred for male respondents. Such trend is mirrored by the combined levels, where the combination describing the most desirable conditions (HR-HS) receives only female preferences, whereas that depicting the least desirable conditions (LR-LS) shows a significant male preference. This picture seemingly suggests that female respondents tend to more positive positions towards their municipality, especially compared to the male counterpart, which tend to be associated to more negative views. These trends might be informative when trying to anticipate the local attitudes towards specific themes. In particular, this kind of information might support the design of communication strategies towards specific stakeholders, in order to raise awareness where it is lacking or promote local capacities where they are not visible.

The other demographic characteristics describe a situation where the younger groups are related to less positive perspectives on their communities, to the point that no young respondent (aged between 18 and 34 years old) indicated either of the highest levels. On the contrary, the eldest groups tended to provide more optimistic views. Thence, it appears that the younger generations are the most discouraged in terms of local capacities to deal with flood risk and environmental issues. At the same time, within each level, the groups with the highest education attainments tended to be more related to the highest levels, suggesting that education might positively influence the approach towards the local conditions. Drawing generalisations from the class of income might be inappropriate given the significant prevalence in the first two. Nevertheless, it might be noteworthy that the few respondents pertaining to the higher class overall agreed on the medium levels of both *cores*, thus suggesting that income does not significantly influence the conception of the community. Lastly, in terms of knowledge and experience of the local dynamics, it appears that a longer period of residence tends to extremise judgements, whereas residents for intermediate periods of time tend to exhibit more moderate standpoints. In brief, youngsters tend to own more pessimistic representations of the disaster and environmental capabilities of their communities, whereas elderlies and more educated citizens tend towards more positive views, and wealthier or less stable residents assume milder positions. As a consequence, it appears that the composition of the population might indeed affect the overall perception of the local disaster resilience and environmental sustainability, thus also shaping the expectations when considering the development path of a municipality.

Further information might come from the comparison between assessed and perceived levels. This process would allow to verify if the judgements of the respondents meet the numerical evaluations, that is if the picture drawn from quantitative analyses corresponds to that formed by local communities. Also, it might verify whether some significant characteristics of the local communities were not addressed by the computations; or inform on the grade of awareness on either local capacities or issues. In this case, the most evident feature that emerges is the substantial mismatch between assessed and perceived levels. In other words, in general, the judgement of the locals does not correspond to the characterisation that numerical indicators propose. The general convergence of the preferences towards the perceived medium levels of both *cores* inevitably leads to a discrepancy to the assessed levels (as municipalities were selected in order to represent each a different level). A further consequence is that perceived levels of resilience and of sustainability usually do not correspond to their respective in the combined assessed level: for instance, the respondents associated to the highest level of resilience (HR) mainly belong to municipalities assessed on a MR-MS or a LR-MS level, hence with a completely different assessed level of resilience. Such differences are even more evident when comparing the combined levels, both perceived and assessed. Indeed, for instance, none of the respondents residing in the most performing municipality actually perceived these favourable conditions; rather, the local citizens were associated to more dire perceptions, up to diametrically opposite to the assessed level of their community (LR-LS, LR-MS, MR-LS). Furthermore, it might be noteworthy that the combination of perceived levels led to the presence of combined levels that were not detected by the previous quantitative process: LR-LS was not present throughout the Marche region, while HR-LS was not present among the selected municipalities for the collection of the local perspectives. These levels are especially meaningful, as they represent some of the most critical conditions, that correspond, respectively, to a crisis of the basic services of the community (*collapse*) and to an unbalanced development that strengthens human capacities disregarding natural equilibria (*resilience trap*). Recognising such a perception (of a municipality in perceived though possibly unreasonably dire conditions) is extremely significant to comprehend the point of view of the local populations. It might be informative to foster and optimise efforts to raise awareness on the local capacities devoted to risk management and environmental preservation. Then, a sounder relation of the population with their surroundings might influence the overall attitude towards local processes and everyday life. Indeed, consolidating a sense of belonging and a consciousness of the local issues might be beneficial to foster personal engagement and common proactivity to strengthen the community.

A further area of discussion revolves around the questions mirroring the indicators employed in the first phase of the quantitative assessment. This exploration reveals that, in general terms, local communities feel like their municipality is not changing, at least in the features that were assumed as most significant to detect the resilience capacities and the sustainability commitment. This is demonstrated by the overall preference to moderate opinions, regardless of the perceived or assessed level of the related municipality. Furthermore, it appears that the most extreme views were related to the worst perceived status, as if the perception of residing in dire conditions exacerbated the overall judgement. This might imply a more generalised discontent, calling to be addressed. The only outlier in this picture is represented by the highest level of sustainability, which indeed matches the evaluation of the green area transformation. This seemingly suggests that in spite of the other topics, being the anthropic use of water and the conditions of wildlife, the preservation of natural areas is especially significant to identify the appreciation towards endeavours devoted to improving local sustainability. In particular, allowing natural areas to expand seems related to a rather positive conception of the local ability of human communities to coexist with the natural environment, that locals would probably strongly support.

The investigation around the association among perceived levels and seemingly quantitative indicators allowed also to draw the definition of the levels of resilience and of sustainability as they emerge from the expressed preferences. The previous quantitative assessment first compared the values of such indicators across the municipalities and delimited groups of homogeneous characteristics (Fig. 14.1 and Fig. 14.3). Then, the definition of higher or lower levels emerged from the interpretation of such groups in terms of trends of the indicators. On the contrary, in this case the perceived level of resilience and of sustainability was already known (as derived from the analysis of the questionnaire), hence it was possible to associate each level to the trends of the same indicators, in terms of frequency of preference (Fig. 14.2 and Fig. 14.4).

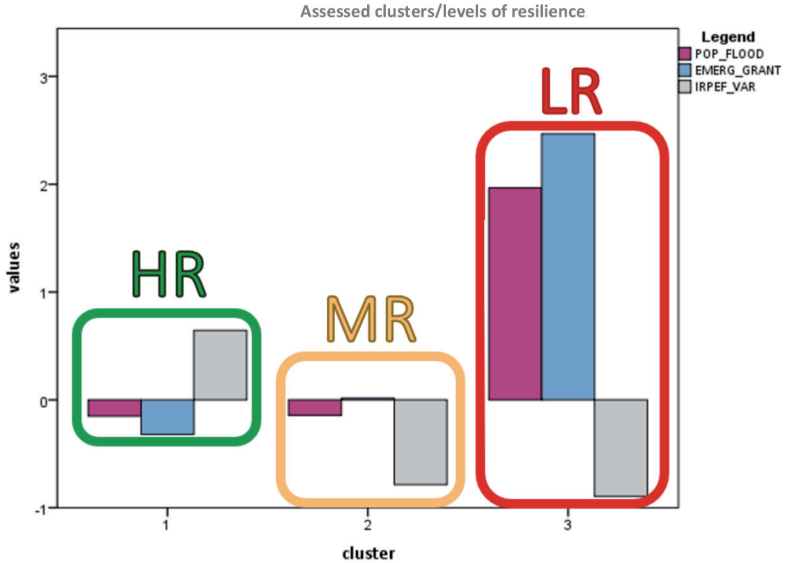


Fig. 14.1 - Clusters and levels (low L, medium M, high H) of assessed resilience (R)

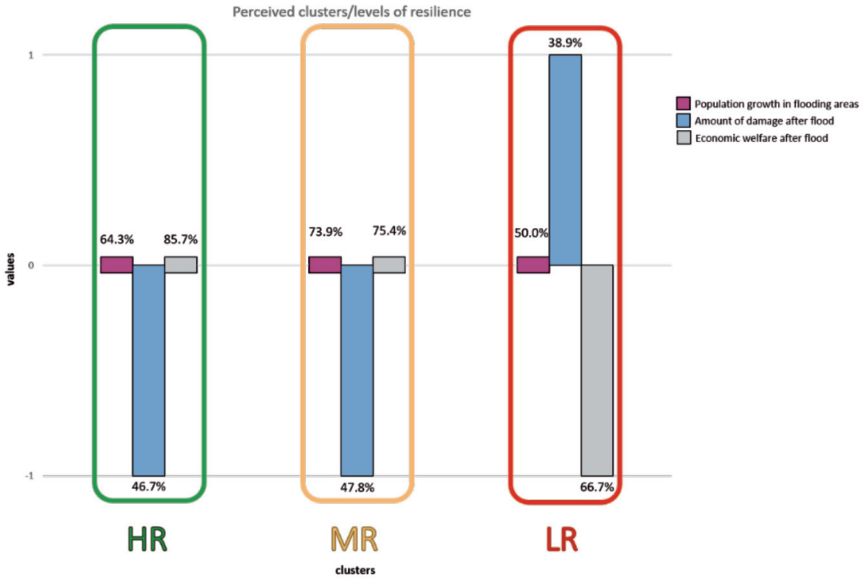


Fig. 14.2 - Clusters and levels (low L, medium M, high H) of perceived resilience (R)

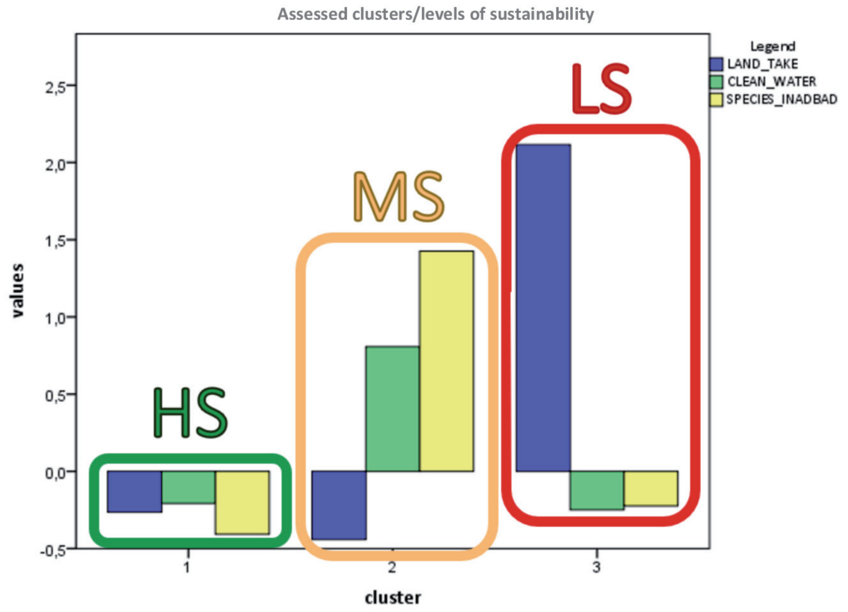


Fig. 14.3 - Clusters and levels (low L, medium M, high H) of assessed sustainability (S)

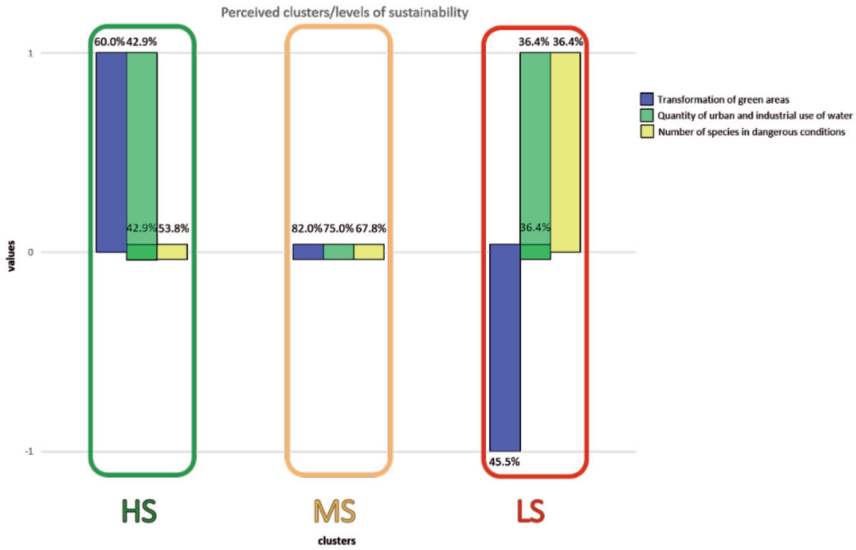


Fig. 14.4 - Clusters and levels (low L, medium M, high H) of perceived sustainability (S)

When confronting the drawn clusters, it is necessary to preliminary acknowledge some significant differences. To begin with, the quantitative assessment allowed to evidence a grade in the trend (for instance, how extensive is the exposure of population to flood), whereas the perceived clusters show either an increase/decrease or an invariance. Furthermore, the representation of the transformation of green areas holds opposite meaning in the two representations, as in the quantitative assessment "more" means an increase in the magnitude of conversion of natural to anthropic areas, while in the perceived assessment "more" translates into wider natural areas. Apart from these differences, the comparison is still feasible, and it shows that also in this case quantitative and perceived estimations do not seemingly agree. Indeed, the quantified and preferred tendencies generally do not match within the same level, either of resilience or of sustainability. The comparison is partially more encouraging when considering the high level of resilience (HR), and especially the extreme negative levels (LR and LS), that exhibit a rather high adherence, notably for the *resilience core*. This appears to suggest that the fundamental features that might be recognised as significant for an analytical process do not necessarily correspond to the priorities of the local populations. However, the direst conditions seemingly lead to an agreement of the quantitative and qualitative assessments, suggesting that in this case the traits associated to the most negative status are both numerically detectable and individually perceptible, as well as concerning the same issues. In this case, it might be relevant to observe that the most discriminating factors were the effects of flood events for resilience and the integrity of natural systems, both in terms of unaltered vegetation and of endangered species, for sustainability. This information might provide further insights when planning strategies to address the local issues, as numbers would deliver trends of concern, while perceptions would provide the urgency of action.

Lastly, the outcomes of the questions that received the most inhomogeneous responses resulted similar to those related to the averaged level of each municipality. Indeed, when questioned about flood risk management, it seems confirmed that locals tend to attribute more substantial reliability to self-capacities, rather than to the abilities shared within their community. Such a general distrust might be especially detrimental during emergency, when social bonds are pivotal to cope with and overcome the event. When coming to sustainability, such a negative view concerns the efforts spent to mitigate human impacts in terms of pollution, although the judgement on the role of human activities on the riverine equilibria is ambiguous. Indeed, this appears to confirm that though the effects of anthropic processes on the natural environment is generally acknowledged and despised, there is still some trust in the human capacities to restore, nurture and improve the conditions of the natural environment. This faith might hint to the willingness to advocate sounder strategies to foster the local environmental sustainability.

14.3. Emerging traits of the local communities

Some closing considerations relate to the sections of the questionnaire investigating specific traits of the local capacities, providing further insights on the local perceptions and conditions.

A first topic concerned how local authorities responded to flood risk, and in particular what kind of strategies were performed to reduce its probability of occurrence. It appears that the most recognised activities are those based on engineered solutions, that affect the built and natural environment, especially in comparison to non-structural measures that affect human behaviour and attitudes. It might be noteworthy that the reported frequency of implementation is based on the observations of the locals. Consequently, while alterations of the built or natural environment might be rather evident, in the absence of substantial communication efforts other measures might pass unnoticed. This might be especially true for strategies that often remain confined to technical offices, as for instance urban plans and risk maps, although the involvement of communities might be particularly effective in raising awareness on local critical issues and on the available response capacities.

When questioned on the susceptibility of local assets, concern appeared to converge towards the private and the productive domains, followed by the transportation system. Although the assumed scenario was hypothetical, the preferences might have been reasonably influenced by the actual experiences suffered by local populations due to the occurred floods. In this case, it appears that flood events can significantly and directly affect the most identifying domains of a common daily routine, being home, workplace and commuting. This might suggest a priority of action for the development of local emergency plans, as integrating continuity plans for the everyday activities of laypeople might be particularly appreciated by local communities. Whereas the apprehension for the private sphere seems to be consistent, the public domains results rather resistant with regards to flood risk, thus suggesting a sound reliance on public services even during critical events.

The limited participation of local populations in risk management endeavours is confirmed by the low awareness of the enacted planning strategies, thus suggesting a significant margin to improve risk information and communication campaigns. These efforts might also help to narrow the gap between public authorities and local populations, thus contributing to building that trust that is pivotal to face a disaster emergency as a cohesive community. Notably, respondents reported to be most familiar with Municipal Civil Protection Plans, with various level of detailed knowledge, and that the major source of information were acquaintances or web-based official media of local authorities. Consequently, communication strategies might take advantage of such insights by favouring targeted stakeholders and social media when delivering information related to risk prevention and reduction. Additionally, it appears that the higher the level of the local authority and the further it is from local populations. Consequently, a more pervasive engagement of local communities in planning and management endeavours performed at higher scales might be particularly informative as well as effective in raising awareness on the proactivity of local authorities at every level, along with potentially contributing to strengthening social trust in the overall governance system.

Indeed, this kind of trust emerges when considering a hypothetical emergency scenario. Respondents appear equally reliant on personal skills, acquired through a learning process, and on external help, whereas previous flood events seem less relevant. Unfortunately, in this case it is not possible to differentiate if the belief on external support was placed on local authorities or fellow citizens, though it still suggests a mild sense of cohesion.

Along with themes related to resilience, a further topic concerned the sustainability of local communities. In particular, the interest was focused on the perceived changes of the local landscape. In this case, most respondents reported an alteration of natural areas due to further urbanisation processes, especially in the municipalities already more developed and advantaged from a socio-economic perspective (Jesi, Falconara Marittima and Fabriano, in order of expressed preferences). Nevertheless, this question was complementary to the information concerning the amount of observed alterations of natural areas, that was most frequently considered as limited. Indeed, some of the respondents reported an actual expansion of natural areas. As a consequence, it appears that the dynamics of urbanisation and industrialisation are perceived as not significantly affecting the surveyed local communities, seemingly lying in a sound equilibrium with their surrounding natural environment.

15. Partial conclusions

The *objective* of the presented integration to the overall framework was the inclusion of the standpoints of local communities in the quantitative assessment of the levels of resilience and sustainability of some selected municipalities. In particular, the involvement of locals sought to incorporate their thoughts in the identification of the priorities in terms of disaster and environmental management. To this end, the analytical methodology was amended with a qualitative approach, leading to the revised **CAReS+ methodology**, that was applied to a case study of six municipalities comprised within the Esino river basin, in the Marche region.

In particular, the *first part* of this qualitative research focused on the identification of the perceived levels of resilience and of sustainability. When averaging the responses over a specific municipality, the outcomes delineate a homogeneous picture. Indeed, all the municipalities were represented as lying in **medium conditions** of disaster resilience and of environmental sustainability. This portrait is in substantial contrast with the assessment provided by the employment of numerical indicators. The emerged homogeneity itself disagrees with the quantitative evaluation, as the municipalities were selected to represent all the different levels that could be identified in the region. Turning to the perceived levels on an individual basis, that is losing the information relating to the municipality of belonging, a more variated picture emerged. Even though the wider preference towards moderate views on the local conditions was still evident, the most preferred combinations hint at a general discouragement in the local capacities to deal with flood risk, while opinions on local sustainability were more distributed. Consequently, it appears that **disaster resilience** is the theme most affected by a significant mismatch between assessed and perceived conditions. This outcome suggests that it might be beneficial to further the investigation about the causes of such severe views. Indeed, identifying the issues that prevent the local population from acknowledging the capacities of their community might be especially important, in the perspective of strengthening the social bonds and trust that are fundamental for a comprehensive development of the community, as well as for a cohesive response to extreme events.

This picture appears confirmed by a *side part* of the analysis that involved the characterisation of the **clusters** (of resilience and of sustainability) based on the expressed preferences. This exploration was based on the questions designed to represent as closely as possible the indicators employed in the first part of the quantitative analysis. The general discordance between assessed and perceived metrics was reinforced, suggesting that some significant factors leading especially to positive perceptions of the municipal conditions might not have been included in the quantitative indicators. The lowest extremes provided an exception, particularly for the resilience side. Indeed, not only the assessed and perceived trends agreed, but they also concerned the same indicators. As well as they resulted more significant in the quantitative analysis, considerations related to the **impacts of flood events** seemed to affect the perception of the locals significantly and negatively in terms of resilience, similarly to the **integrity of the natural environment** affected the local perception of sustainability. In other words, memory and experience might indeed significantly influence the local perception of disaster resilience, whereas a sound relation with the environment might be a valuable asset for local populations. Throughout such key topics, moderate judgements were the most common on the changes concerning the municipalities, regardless of the perceived level and scale of assessment. Hence, it seemed that there is a generalised perception of immutability that not even flood events could significantly alter and that pervaded all the proposed themes.

A further *side part* of the investigation appeared to provide additional insights on this sense of immutability. Indeed, although the few changes of the local landscape were frequently reported for the urban settlements, it was possible to trace also the trend concerning the expanding natural ecosystems. It appeared that the **processes of transformation** of the local landscapes are perceived as almost **balanced**. In particular, the effects of anthropic activities on the natural environment were indeed noticed, also in terms of measures to mitigate flood risk, as for instance the **management of the riverine area** was frequently reported. Notably, a similar awareness did not relate to those risk reduction measures aiming at influencing human behaviour or governance. Indeed, local respondents resulted **scarcely familiar with strategic, management and emergency plans** and even when informed, often the initial clue was provided by

informal means of communication, such as social media or word of mouth, and usually led to local plans, rather than policies developed at higher scales. Nevertheless, it appeared that the received information was at least partially effective in educating in the proper disaster behaviour, as in case of emergency equal confidence was entrusted in personal **learnt skills and external help**. In this context, a consistent concern surrounding the assets that shape common daily routines emerged: **houses, workplaces and roadways** were depicted as the most susceptible elements of the local communities.

The exploration of the issues surrounding the collapse of a community drove the *second part* of this research section. In particular, locals were asked to identify the most important assets and services, of both human and natural systems, as well as the accepted degree of their loss. In this case, a significant divergence between the *cores* became even more evident. Indeed, the response to the themes related to the environment received an overall agreement, as services connected to **food, air and water** were recognised as priorities and a limited tolerance was exhibited for the entity and duration of damages suffered by natural systems. On the contrary, resilience-related themes received more differentiated responses. Overall, communities seemed to especially care for **health, work and education**, though a certain degree of loss is sometimes accepted, even for relatively long periods. Consequently, it seems that on the one hand, **environmental issues were perceived as compelling,** and their solution should always be prompt. On the other hand, local authorities are expected to focus on the continuity of the healthcare system as well as of the productive and educational systems, although the accepted degree of loss might be higher. These considerations are particularly informative of the priorities and the themes would especially gather the local endorsement. As such, they should be included in the local resilience and sustainability management plans and activities.

The *third part* of this research section investigated the association among some main socio-demographic variables and the perceived levels (of resilience, of sustainability and combined). It might be noteworthy that, due to the dissemination methodology, the possible emerging associations would be related not only to the recorded perceptions, but also to the willingness to participate and thence to be engaged in the resilience and sustainability issues concerning their community. In this case, the typical responding profile was of a middle-aged woman, with a secondary level of education and a medium-low income, who had spent most of her life in her municipality. More in detail, it emerged that **female** respondents tended to be provide more positive judgements of the overall local conditions compared to the **male** counterpart. Another influencing factor appeared to be the **age**, as younger generations shared a more pessimistic view on the local capabilities, possibly influenced by an overall discouragement also due to a higher awareness of environmental issues. On the contrary, achieving the highest levels of education seemed related to more positive conception of the local area. Lastly, shorter periods of residence in the area tended to translate into moderate judgements. Notably, the relevance of gender and age was recognised also by the quantitative assessment, while income and education were recognised as a less significant influence, at least for the *resilience core*. Hence, a mutual validation appears to emerge between the quantitative and qualitative assessments, substantiating the emerged outcomes. Furthermore, these results suggest that where resilience and environmental endeavours are successfully implemented, it might be especially important to increase their visibility to the more sceptical groups.

Overall, the main purpose of the survey was to provide a tool to collect the perceptions and the conditions of local communities that could be comparable and possibly integrated with the quantitative assessment. Consequently, though the overall response to the questions was the main focus, a more detailed analysis delivered some further significant insights. Hence, a *fourth part* of the research was dedicated to the identification of some emerging specific features of the communities. In general terms, such topics concerned local **awareness and efficacy in dealing with flood risk**, **flood impacts**, **human effects and endeavours for the environment**. In particular, awareness to flood risk received a rather homogeneous response. Indeed, regardless of the scale of analysis and of the perceived level, there seemed to be a significant confidence in the personal knowledge and awareness around these themes, while higher scepticism concerned the other components of the community, becoming actual distrust when addressing the potential ability to cope with a flood event on the base of the available resources. At the same time, there appear to be a shared uncertainty over the actual efficacy of the community, at any scale, of dealing with a flood event. Nonetheless, in general terms a moderate if not optimistic judgement on the possible consequences of a flood event was recorded when considering the responses on a municipal level, thus suggesting an overall conception of limited vulnerability and exposure of the municipality to flood risk. Other topics of discussion concerned the efforts to mitigate human impacts on the natural environment. Also in this case, a general discontent emerged, especially towards the endeavours to reduce pollution, though it was noteworthy that the judgement on the effect of anthropic activities on the environment was not unanimous, though often not positive. In brief, it appears that locals had the highest confidence in personal abilities and knowledge with regards to flood risk, with a discouragement that became particularly evident when considering the efforts to preserve the natural environment. Nevertheless, locals appeared positive on the possibility to nurture natural ecosystems, thus supporting their potential engagement in order to both strengthen mutual trust and foster local sustainability.

Conclusion

A general overview

The funding ground of this study was the recognition of the inherent complexity of the coexistence of humans and nature, that shape social-ecological systems. The overarching aim was to contribute to reconstituting a coexistence between humans and nature that would encourage mutual nurturing and inhibit mutual destruction. In brief, the major drive of this research was to contribute in the common efforts to reduce disaster risk, thus fostering the survivability of complex social-ecological systems. Consequently, this research intended to develop a model of those complex dynamics and then to design a methodology to translate descriptive indicators into insightful information for local policies. To this end, the panarchy heuristic served as the starting point to first outline the Social-Ecological Panarchy Model and then outline the Combined Assessment of Resilience and Sustainability Methodology (CAReS, then CAReS+ methodology).

The *first part* of this research focused on adapting the *panarchy* heuristic to the definitions and assumptions of disaster science. Risk and its components, hazard, vulnerability and exposure, could find an interpretation within the adaptive cycles of complex social-ecological systems. At the same time, the discussion needed to include environmental issues, as the interaction between humans and natures appeared mutual and intrinsic, to the point that disaster resilience and environmental sustainability could find their simultaneous definition. The subsequent model then constituted the basis for the analytical methodology.

Thence, the *second part* of this research focused on the development of an assessment method that would address disaster dynamics, while being able to include risk and environmental themes, and provide both a classification and a characterisation of the units of analysis, in this case municipalities. As a consequence, the methodology was composed of two phases. The first phase was based on a *cluster analysis*, in order to group municipalities into clusters of homogenous behaviour in terms of capacities of dealing with flood risk and environmental issues, thence associating them to different levels of resilience and sustainability. Then, a second phase of analysis employed a *discriminant analysis* in order to identify the most relevant features of the municipality that would contribute to the determination, and possibly prediction, of that behaviour before extreme events occurred.

Lastly, a *third part* of the research focused on expanding the analytical approach, by accounting for the perspective of local populations. Consequently, *questionnaires* were designed to gather the perceived level of resilience and of sustainability. Furthermore, with the aim of engaging local populations in the definition of the priorities of their communities, local opinions were collected to identify the basic functions of the system, both from the human and the natural side, and the tolerance over the loss of such functions. A comprehensive analysis of the responses was also expected to shed to light on some specific attitudes of the local communities.

An overview on the theoretical outcomes

The application of the panarchy heuristics to social-ecological systems allowed to strengthen the intuition that the survival and development of such coupled human-natural systems depend on constant *change*, *transformation* and *adaptation* to internal as well as external drivers. It also confirmed that the consequences of those shifts might either consolidate the overall hierarchy or trigger the propagation of disruptive flows. The question of how to deal with those destructions is especially relevant when the concerned component of the social-ecological system are human communities. In this case, the problem becomes twofold: disruption should not occur to the community, as much as the community itself should not cause disruption to the surrounding environment. That is how resilience and sustainability became the *cores* of the following discussion. Nevertheless, the theme of change fostered further insights addressing the theme of risk management. Indeed, the visualisation drawn from the Social-Ecological Panarchy suggests a novel interpretation of *risk* as a potential, vicious interaction among human and natural components of a same system. Here, the concept of risk retains its intrinsic sense of uncertainty and emphasises the requirement of an alignment of susceptibilities for disasters to happen. In particular, hazards are represented by the inherent processes occurring within a component, whereas the vulnerability and exposure of an other component become the necessary condition for a destruction to cross scales and evolve in a disaster, that is the manifestation of that potential risk. Notably, such definition might also be considered "neutral", in the sense that anthropic as well as natural components might either be at the starting or at the ending point of disruption, thus hinting at a possible, more general interpretation of the concept of risk. In light of these observations, the proposed theoretical paradigm appears suitable to model different disaster dynamics. Even though natural hazards are easier to identify as external threats to human communities, man-made incidents still belong to the overall framework. Indeed, if such incidents caused environmental damages, they would be a confirmation of the previously mentioned dual interpretation of risk. Nevertheless, if the consequences remained confined within the anthropic component, the model might only need an appropriate adjustment, as the proposed definition of risk would still be valid.

An overview on the quantitative outcomes

The application of the quantitative approach involved two case studies, the Marche region and Hokkaidō, similar for morphological as well as socio-economic features. The association of the respective municipalities to the different levels of resilience and sustainability returned rather different outcomes. Indeed, the municipalities of the Marche region appeared to more extensively lie in *desirable conditions* compared to the Hokkaidō case, where *intermediate conditions* were more common, though increasing in terms of sustainability. Although the levels were differently populated, they were similarly distributed over the territories of the two case studies. Indeed, the most critical conditions could be commonly traced in small clusters of undesirable conditions located in the *mountainous and hill areas*.

The elements that more significantly led to this classification were the *consequences of flood events* and the direct impact of human processes on the *alterations caused to the natural environment*. While these traits could be interpreted as typifying the local behaviour in case of a critical event, it was also possible to identify the features that influenced such behaviour. With regards to resilience, for the Marche region *socio-demographic features* and the size of the *volunteer corps* resulted especially significant, whereas for Hokkaidō the robustness of the *welfare system* prevailed on any other facet. With regards to sustainability, in both cases the presence and extent of both *natural and cultivated vegetation* resulted pivotal.

Recomposing the Social-Ecological Panarchy, it appeared a rather encouraging status for both case studies. Indeed, in both cases the *fore-loop* was extensively populated, with a slight tendency to move towards the *conservation phase*. These considerations suggest a rather sound coexistence between humans and nature in both cases. Nevertheless, the presence of either *resilience* or *sustainability traps* evidenced the existence of an unbalanced weight of one *core* over the other, that limit a global effective development. In addition, issues could be more easily identified for the *sustainability core*, though the most encouraging performances were less common for *resilience core*, thus suggesting where more urgent concerns lied as well as where further improvements should be placed.

An overview on the qualitative outcomes

The application of the qualitative approach involved six case studies in the Marche region, that are six municipalities lying within the Esino river basin, distributed from the mountains to the coast and selected in order to represent different levels of resilience and sustainability. In this case, the emerging outcome is extremely homogenous, as all municipalities were perceived as related to *intermediate levels* of resilience and sustainability. Although this prevalence was confirmed when exploring individual responses, at that latter scale of analysis the preferences to the other levels appeared, with a slight tendency to the less optimistic views. Indeed, this discouragement could be even more visible when considering the combined perceived levels, in which case the *medium-low evaluations* were more common. As a consequence, it appears that even though the overall judgement of the local conditions is moderate, the individual response tends to more pessimistic views, especially on matters concerning *disaster resilience*.

The outlining of the clusters, in analogy to the quantitative analysis, evidenced a rather similar representation of high and intermediate levels, whereas the lowest levels were the most distinctively defined. In this case, the most relevant traits were the *impact of flood events*, in terms of dire consequences for the communities and for the households, and the *integrity of natural ecosystems*, in terms of alteration of vegetation and magnitude of endangered species. Nevertheless, in general terms, preference was still agreed to moderate opinions on the key indicators of local resilience and sustainability, associated with a widespread sense of *immutability* of the local features and processes.

When exploring the features that might be most relevant in determining a certain response, it appeared that *gender* and *age* were especially significant on driving the preferences. Indeed, females tended towards more positive judgements than males, whereas younger people expressed more sceptical feelings. At the same time, higher educational attainments appeared related to more positive opinions and shorter periods of residence to more moderate ones.

A general exploration of the responses brought to light unusual responses when some specific topics were proposed, being the awareness and efficacy in dealing with flood risk, flood impacts, human effects and endeavours for the environment. In these cases, the answers did not match the associated perceived level. In particular, the question on *self-awareness* to flood risk polarised the opinions towards the highest positive end, on the opposite of the *potential efficacy of the community* in case of a flood emergency. At the same time, discontent emerged when addressing the endeavours fostered to mitigate the *anthropic impact* on the environment, especially in the form of pollution.

Lastly, consistent apprehension of the local populations emerged for those assets related to the most significant domains of daily lives, that are *houses, workplaces and roadways*. In terms of *flood risk reduction,* measures were primarily recognised as affecting the natural riverine system, whereas the non-structural strategies intended to raise awareness and inform the communities were rarely recalled. In particular, a limited familiarity with the enacted *policies* emerged evidently, especially when pertaining authorities other than the local municipalities. In the case of *local emergency plans*, pivotal for the coordination of the community response, *informal ways of communication* appeared to constitute the major means of information, that delivered effective lessons concerning appropriate disaster behaviour, although the reliance on external support was still significant.

An overview on general trends

The methodological framework was developed into two research lines, a quantitative and a qualitative one, designed to mirror and cross-check each other. Hence, the comparison of the respective results might be especially meaningful. Furthermore, the application of the quantitative paradigm to different case studies might provide additional insights on the general tendencies.

The foremost outcome is the substantial mismatch among assessed and perceived levels of resilience and of sustainability. In other words, the evaluation provided by indicators does not agree with the judgements of locals. This might suggest that some local phenomena might have affected the local view on the capacities of the communities, but were not appropriately captured by the selected indicators. Notably, perceptions tended towards moderate and eventually pessimistic conceptions of those municipalities that were generally assessed as in medium-high conditions. This mismatch should not be underestimated: perceiving direr conditions might hamper the general trust towards the community, whereas perceiving sounder conditions might translate into inappropriate behaviours. Nevertheless, this result might also question which the "real" conditions are. In this case, it might be relevant to delve into the events and processes that led to such differences and accordingly take action, possibly revising the overall assessment.

In spite of the different outcome, both research lines converged towards the identification of flood impacts and alterations of the ecosystems as the most significant factors to define the assessed levels of resilience and sustainability, respectively, while gender and age resulted the most influencing factors on the perceived levels. Notably, these results were valid for one of the case studies (the Marche region). Indeed, for the other (Hokkaidō) the assessment suggested the relevance the indicators related to the soundness of the welfare system as most significant in defining resilience, thus specific investigations are required to reveal the features of each case study, preventing direct generalisations.

Overall, the methodological framework was founded on the theoretical paradigm centred on the panarchy heuristic. Hence, at this point it might be possible to recompose the picture through the panarchy metaphor, although only for the case study of the Marche region. The quantitative assessment describes a social-ecological system mainly lying in the most desirable conditions, with a slight tendency towards the more concerning status of consolidated yet rigid processes. Nonetheless, the presence of unbalanced development paths, favouring either resilience or sustainability themes, should not be underestimated. This especially holds true in the light of the overarching assumption of the present research that identifies a balanced equilibrium between resilience capacities and sustainability efforts as the pivotal element for a long-term, sound coexistence between humans and nature. A critical point of the development cycle described by the panarchy is the moment of collapse of the fundamental and characterising functions of the social-ecological system. Hence, it is pivotal to identify first such functions and then the critical thresholds. In this regard, local communities recognised the health, productive and educational services as defining disaster resilience, and food, air and water services as essential for environmental sustainability. In terms of thresholds, there was a rather high tolerance over service interruption in relation to resilience, and a similar relatively long period could be accepted before their restoration. On the contrary, for the sustainability side, any grade of loss was considered unacceptable, and the recovery of the services was required to be prompt.

In light of these findings, it appears that local populations tend to underestimate more extensively the resilience abilities of their community, especially expressing scepticism about the local potential to effectively cope with extreme and threatening events. Consequently, it might be particularly beneficial to promote campaigns to consolidate resilience and awareness of the available capacities, directly engaging the whole community, in order to build social trust as well as political endorsement. In this regard, the concentration of the least desirable conditions in the innermost mountainous and hill areas suggests that chronical developmental issues might contribute to these undesirable conditions, hence it also suggests where further funds are most needed. At the same time, the judgements over the endeavours to foster the sustainability of the community found a generalised discontent, especially in terms of reducing the detrimental effects of human activities on the environment, thus suggesting a common call to improve the relations of the communities with the surrounding natural systems. In this regard, the cautious confidence in the possibility of humans to positively contribute to the preservation of natural equilibria might confirm the willingness of the local populations to actively engage in projects devoted to the natural environment.

An overview beyond

The present study developed and applied a theoretical framework, the Social-Ecological Panarchy model, and a methodological framework, the Combined Assessment of Resilience and Sustainability methodology. Although the outcomes of their implementation appear encouraging, improvements are needed to strengthen the overall reliability.

For instance, the association among the *adaptive-cycle phases* and the levels of resilience and of sustainability could be thorough reconsidered, in particular more detailed, including a wider range of nuances in the assessment. In this way, it might be possible to capture a more varied range of local capabilities related to resilience and sustainability. In a similar vein, a broader set of indicators, both for the first and the second phase of analysis might be beneficial to better comprehend local conditions, although the difficulty in retrieving relevant information remains a significant limit. In this case, it would be particularly meaningful to gather data tailored to the local characteristics, as it would be most suitable to grasp local dynamics. The integration of the opinions and judgements of the local population might be especially informative in this regard, as they might provide an informed view on the events and processes occurring in their area. At the same time, extending the involvement in the surveys to a wider case study or to other case studies might provide further insights on common preferences or specific traits of the communities. In addition, the design of this methodology is based on comparative considerations. As a consequence, the drawn outcomes are valid only within the considered social-ecological system and they do not allow direct comparisons among different systems. Actually, not only the outcomes, but the assessment structure itself should be considered as context-specific, meaning that indicators as well as questions were designed in order to address local features. Consequently, while the overarching structure maintains its significance, the operative assessment tools (namely indicators and questions) might not be immediately applied to other case studies, but they should rather be revised and adapted to local conditions. Additionally, the first analytical phase that employs a cluster analysis is particularly sensible to the change of the indicators, hence the identification of the most meaningful indicators to be included should be the priority. Moreover, the second analytical phase delivers a so-called "predictive function", that is a technically rigorous term, but should be taken with caution; the output of the discriminant analysis is intended to provide information in support of local governance, but it remains a tool to be used with a critical approach and together with other ones.

In addition, it is here stressed that this study elaborated the first application of the proposed methodology. Therefore, the foremost aim was to verify if such methodology was suitable for implementation, given the different context of operation. In this sense, the comparative study was primarily intended as a means to reveal possible practical issues, especially in the selection, feasibility, and adaptation of the indicators. However, the quality of the results appeared consistent, and they seemed reliable in terms of observed trends and local properties.

Although acknowledging the mentioned limitations, the proposed model and assessment methodology still appear to hold a potential.

For instance, the suggested generalisation of the concept of risk might contribute to the current endeavours of bringing together disaster and environmental sciences by providing a possible point of connection, thus stimulating further discussions on how to effectively enhance an integrated development of human communities with the surrounding natural ecosystems. At the same time, the implication that change is inherently necessary and unavoidable poses some questions on how change should be allowed within a complex coupled system. From the perspective of disaster, this theme transforms in a matter of both risk management and governance. Indeed, how to deal with change translates in a preference to resistive or adaptive approaches of risk management, that is preferring to control nature or transform societies. On the other hand, governance comes into the debate when considering what kind of change to promote within communities, that is optimising assets or promoting flexibility. The proposed theoretical model suggests that in general terms, within coupled human-natural systems, transformations should be favoured for the anthropic components in terms of continuous adjustments to the feedbacks coming from the natural components. What should be privileged, where more efforts should be put, where critical issues lie are all concerns that the assessment methodology tried to address. This is not intended to deny that eventually an extreme event will severely affect a community: the point proposed here is to provide a tool to support governance action while there is room for adjustments. Though the results were limited to the case studies, the implementation of overarching framework can be extended to any other community. In addition, even though this application was meant to deliver a first, static picture of the conditions of some communities and of their surrounding environment, the process could be applied again in the future to monitor the possible variations and thus outline the development path of these communities. This effort might be especially beneficial to identify in advance circumstances that could lead to concerning conditions, up to hampering the local capabilities of dealing with extreme events, both man- and nature-made. At the same time, the insights that both the quantitative and the qualitative processes deliver might be informative for the local development strategies and plans. As commonly and internationally advocated, the expectations and the priorities of the locals that emerge from the investigation should be included when defining the targets and plans of the community, and the proposed methodology was designed specifically to assist in this kind of endeavour. Furthermore, in-depth interviews and more extensive confrontation with local stakeholders might provide valuable information, that could not only enrichen but also strengthen local development planning. In addition, the engagement of local populations would support their contribution to the achievement of the shared objectives, while addressing behaviours and practices that hinder the thorough consolidation of resilience and sustainability.

In conclusion, disaster resilience and environmental sustainability might be considered more attitudes than properties. In this sense, resilience and sustainability should be constantly nurtured and never taken for granted. Panarchy suggests that stillness is detrimental: the only available path for a sound and comprehensive development is that of a tireless and relentless improvement.

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An interconnected path for social-ecological systems

Decoding human-nature interactions to foster a resilient and sustainable development

In an era of environmental changes, where risks are becoming ever so grave for humans and non-humans across the planet, how to devise a development path that minimizes the threats, looking out for a brighter future?
This research tries to address this question, building on the fundamental tenet that humans and nature are inextricably interconnected, and such an interdependence shapes their shared future. Furthermore, it is time to close the gap between resilience and sustainability when devising a common development path.
To this end, it is necessary a tool to investigate complex social-ecological systems and the inherent, complex interactions. Here, the panarchy theory was revised under the geographical lenses of disaster risk reduction, and social-ecological interactions were decoded to identify a categorisation of desirable conditions for a sound, integrated development. This also allowed to design a novel Combined Assessment of Resilience and Sustainability (CAReS) at the municipal scale, that focusing on flood risk was adapted to two case studies, Marche Region (Italy) and Hokkaidō (Japan). The analysis quantitatively investigated the levels of resilience and sustainability of the municipalities, and then explored the thoughts of local communities on local risks.
Results evidenced the role of flood events in determining the resilience capacities of local communities, and of anthropic impacts in defining their sustainability. At the same time, social welfare and protection appeared pivotal in building local resilience, while the presence of vegetation shaped sustainability. Besides, a substantial mismatch emerged between assessed and perceived conditions of resilience and sustainability, generally in negative terms.
Eventually, this approach is intended to inform risk reduction strategies and local governance, to foster a continuous effort of adjustment and renovation of local communities towards a common, interconnected future.

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La passione per le conoscenze