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From ecological resilience to socio-psychological resilience. Assessing social-ecological and socio-psychological resilience in educational contexts


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# Introduction

Resilience is a widespread concept that is used in various contexts and interpreted from different perspectives and disciplines. Resilience is a concept that has progressively spread across different domains, starting with ecology and then becoming a common framework for communication among scientific disciplines, also connecting science and practice. As a result, resilience is now widely employed in everyday language, generally referring to a certain form of "strength" that enables individuals, systems or communities to withstand and recover from adversities and disturbances. Although its broad use has led to a generally accepted understanding of its meaning, the concept can be explored in greater depth, revealing multiple facets and implications depending on the context or the field under consideration.

For me, resilience is a significant concept, as it encompasses a synthesis of deeper and multifaced meanings, that can be developed through a complex and interdisciplinary panoramic. I decided to focus my research on resilience because it appears to be a perfect concept for understanding life and its evolution, from multiple perspectives. For this reason, I analysed resilience by following the point of view of different disciplines, with particular attention to ecology, psychology and sociology. I also wished to investigate holistic frameworks that emphasize the interactions between all these fields, because their relationships are natural, interconnected, and should be considered as essential feature of the complexity that shapes our lives.

For my literature search, I identified keywords and synonyms, together with other terms, phrases, and related concepts, and then consulted the Google Scholar, Scopus and Web of Science for multidisciplinary, ERIC for educational and PubMed and PsycINFO for psychology databases, gradually narrowing my search until I had identified the literature most relevant to my purpose.

These are important considerations for the resilience of children in educational contexts, as socio-psychological resilience is developed directly through their life experiences or indirectly by recognizing the experiences of other people or, more generally, other living beings. Resilience in educational contexts encompasses individual, community, social and environmental dimensions, integrating both internal and external resources across formal and informal perspectives. In this sense, resilience emerges as an ecological and relational process.

In this research, resilience will be analysed with the aim of deepening the understanding of the concept from perspectives related to educational contexts, identifying the key components and processes that can foster its development. For this purpose, the research begins with the definition of the concept through an interdisciplinary approach and concludes with a review of approaches to its assessment.

In particular, the first chapter highlights the ecological origins of resilience research by examining the key aspects of the concept through the lens of ecosystem ecology. In this section, disturbances and stresses are analysed as factors that precede the possible responses of the system. These responses are examined in relation to the conceptions of equilibrium and stable states, with particular attention to their implications for adaptive capacity. Finally, the role of biodiversity in enhancing ecological resilience is examined.

The second chapter examines psychological and sociological resilience, identifying the different meanings attributed to the concept in these perspectives. The analysis considers resilience at individual, community and societal levels, progressively broadening its consideration. First, the individual point of view is addressed by considering the development of the child and the role of risk factors and positive key determinants in fostering resilience. Second, the analysis expands to a broader perspective, considering the characteristics that support resilience of communities and social systems. This perspective emphasizes the interactions and interdependences between different levels, recognizing that individuals are influenced by increasingly wider social and ecological systems. Finally, the role of response diversity among actors is enhanced as a key quality that fosters resilience.

The third chapter recalls the previous two by examining the interaction between the ecological and the socio-psychological spheres from what has come to be defined as a social-ecological perspective. The interdependence and the profound interconnectedness of these two dimensions are explored to move toward a comprehensive characterization of reality, beginning with the role played by dynamicity and continuous change. Then, adaptation and transformation are highlighted as responses that drive the evolution of the social-ecological system. Finally, the interdependence between the two spheres is declined from both points of view, considering the role of human action in shaping the environment, but also the dependence of human beings on the resources and services provided by it. The chapter ends by highlighting the role of diversity in social-ecological dimensions and considering possible interventions aimed at redirecting human agency towards the development of social-ecological resilience in terms of sustainability.

The fourth chapter presents a review of approaches to the assessment of resilience, declining methodologies, frameworks and tools used to assess ecological, social-ecological and socio-psychological resilience. Through this overview, the analysis progressively addresses the complexity involved in resilience assessment. In order to navigate this complexity, the assessment of resilience in any domain begins with defining the type of resilience being assessed and the disturbances considered in the analysis. Then, the presentation of some of the methods, principles and frameworks focuses on their validity within the multiplicity of approaches currently available for assessing resilience directly or indirectly. The final part addresses specifically educational contexts, integrating the concepts discussed in the previous chapters that are relevant to the assessment of socio-psychological resilience within such contexts. This part identifies the role played by resilience in the field of education, declines the characteristics of the tools currently utilized and discusses future directions to improve them.

# Chapter 1. The dimensions of ecological resilience

The word ecology derives from Greek roots, unifying two concepts: *oikos*, which means "life or household, place to live in", and *logos*, which stands for "word, discourse". The etymology of the term highlights the study of organisms' lives and their "homes", the environments they live in.

The first definitions and approaches to ecology began with Ernst Haeckel, a German biologist who started to consider ecology as an area of biology connected to the physiology of relationships. In 1866 he defined ecology as "the entire science of the relations of the organism to the surrounding exterior world, to which relations we can count in the broader sense all the conditions of existence. These are partly of organic, partly of inorganic nature" (Haeckel, 1866, in Friederichs, 1958, p.154). Subsequent definitions recall the main meanings of the first one written by Heackel, focusing on the presence of both living and non-living components, where non-living nature is usually referred to as environment. Another important dimension cited is the one of interrelationship between the components, in fact, interactions and relationships are at the basis of ecological conception, which concerns a holistic and a reductionist interpretation, based on a hierarchical organization, where higher levels are composed by the integration of the components below.

There are different levels that can be studied in ecology, and it is possible to organize them from the particular to the general: organism, species, population, community, ecosystem and biosphere. Each level contains all the previous ones, multiplying the possibility for interrelations, so that the final effect is produced by more than just the sum of the components. In this sense, ecology deals with complexity, studying the structure and function of nature, in which human beings are also included. In addition, ecology focuses on predictions of what is going to happen in the future, starting from the analysis of the actual situation and above all trying to find possibilities to preserve life and the conditions it needs to thrive.

This chapter will focus on ecosystem level in relation to ecological resilience, occasionally referring also to the other ecological levels as interacting components of the ecosystem. Ecosystem functioning and structure will be examined to understand the mechanisms underlying resilience. Subsequently, some elements that decline resilience characteristics will be analysed, including disturbances, equilibrium, adaptability and biodiversity.

## 1.1 Ecosystem ecology

The study of ecosystems concerns the mutuality between the biota and the physical environment, "such that not only does the environment shape the biota, but the biota transforms the environment" (Holling, 1996, p. 31). In fact, these are the two interacting components of ecological systems, where the biota concerns the living organisms, such as plants, animals and microbes, while the environment consists of air, water and mineral soil. Relationships and interactions between every component are at the basis of ecosystems, which are identified by the areas where these interactions take place. In this sense, the explanation of what an ecosystem represents recalls the same main elements of the definition of ecology.

These two components, non-living characteristics of the habitat and the living organisms present, form the ecosystem's structure from the physical and biological points of view. Living organisms are categorized into species according to their unique morphology, physiology and behaviour. Morphology represents the shape of the organism, physiology is composed by all the living processes taking place in the body of the organism, and behaviour describes its typical way of acting. These three attributes together create the role and the function of all organisms, whether they are bacteria or human beings, within the system.

Resources are another important element for the ecosystem. They are fundamental for organisms' lives, and they can be biotic and abiotic, organic and inorganic. They are objects of exchange within cycles that are continually renewed, because the substances that compose them never vanish, but continue to be reutilized. Matter, which is anything with mass that takes up space, continues to exist in the same amounts, but changes its shape, as well as energy, which stands for the capacity to do work and flows through the system. Both matter and energy follow the general rule where nothing simply is generated or destroyed, but everything transforms and is recycled. Even between energy and matter there is a process of transformation, because to create energy, there must be matter. Everything takes shape according to universal driving forces of energy and matter, where change and transformation are at the basis of nature's dynamics, even if we continue to perceive some constancy in nature. Change is not only normal, but necessary. Our world is constantly changing and always has been, with species becoming extinct and others replacing them. Nonetheless, today more than ever, ecological change is discontinuous and unpredictable, characterized by rare and extreme events, which increase the complexity of facing difficulties and undermine the differentiation between change and destruction, conservation and transformation.

Considering the functional perspective, four main factors can be recognized: abiotic factors and the three "functional kingdoms of nature", which are declined according to "the type of nutrition and the energy source used" (Odum, 1959, p.12), and correspond to producers, consumers and decomposers. These functional kingdoms correspond to the trophic levels of the food web, where different food chains interact with each other, describing the feeding connections between the organisms of a community. The basic distinction of organisms constituting a grazing food web is between autotrophs and heterotrophs. Autotrophic organisms are the primary producers and make their own chemical energy, generally from light through photosynthesis. On the other hand, heterotroph organisms need to feed on other living organisms to get their energy and can be primary consumers, which are herbivores that consume the primary producers, or secondary consumers, which are carnivores that eat herbivores. The food chain does not end with secondary consumers, because there are also tertiary consumers, which are carnivores that eat other carnivores, and other higher levels of consumers who eat organisms of the previous lower trophic levels.

Other than the grazing food web, the detrital food web is necessary for the functioning of all ecosystems, and decomposers are the main actors. Decomposers (protozoa, bacteria, fungi and invertebrate organisms) are responsible for recycling nutrients by decomposing complex molecules into simpler ones, so that the cycle restarts because nutrients are given back to the producers. Basically, trophic levels describe energy transfers and the recycling of matter and energy through passages between organisms necessary for their survival. Through the visualization of these passages, it is possible to understand the transformations that take place inside the ecosystem, recognizing previous and following shapes or amounts of matter (biomass) and energy, also considering the mechanisms of dispersion. Every component of the food web is placed in a situation of giving and receiving, where everyone is resource dependent and survives thanks to the others, especially in the case of the higher trophic levels.

Ecosystems can be of any size, although they usually extend across larger scales, and they are influenced both by internal and external factors. For example, climate and resource inputs are external processes, while availability of these resources in the system, disturbances and interactions between species are internal factors. The external influences can be too harsh and excessively compromise the system, altering irreversibly the equilibrium and bringing a complete change of structure. In addition, ecosystems can be classified in biomes (aquatic or terrestrial areas with specific climate and geography) and cannot exist autonomously but rather interact in a complex and multiple-faced web: the biosphere. The biosphere encompasses all life and where it takes place, and it is composed of the atmosphere, lithosphere and hydrosphere.

"Undergirding the dynamic Earth—its atmosphere, its physical and chemical fabric, and its biological essence—is a prototypical *complex adaptive system* (CAS), one that we call *biosphere*" (Levin, 1999, p.2). Over time the biosphere has built complex interactions between flows of energy and matter, sustaining evolution and preserving the environment to enhance life. As a complex adaptive system, it is based on self-organization, which moves around evolutionary innovations that originate locally. Four key elements at the basis of the biosphere are heterogeneity, nonlinearity (disproportion between effect and cause), hierarchical organization and flows.

In addition, complex adaptive systems refer to three essential features:

- Diversity and individuality of components, where diversity is always maintained and renewed, for example through genetic recombination.
- Localized interactions among the components, including competition for food, predation and reproduction
- An autonomous process, that selects some components, among local interactions, to replicate or enhance (Levin, 1999, p.12).

Finally, since complexity is also a characteristic of the ecosystem, with all its components and interactions between them, it is suggested to separate and identify its elements to simplify the understanding. However, by isolating the variables and controlling them, it is not possible to perceive concretely the mechanisms of the system. In addition, complex ecosystems are characterized by unpredictability, which cannot be simplified. For these reasons, it is necessary to acknowledge these limitations in the analysis of complex systems, seeking to better develop their understanding by considering different aspects.

### 1.1.1 Identity and functionality of ecological systems

The identity of a system depends on its components and the interactions between them. If these two elements are maintained, the identity is preserved, even though innovation and self-organization can be implied. The identity of an ecological system can be "a term to denote the relatively constant properties (i.e. invariables) of a thing/individual; difference is a term to denote the contrary to identity (i.e. the non-identical). Identity and difference serve for the determination of the individuality of entities" (Jax & Jones, 1998, p.255). In particular, Delettre (2020) has found four declinations for the explanation of what identity refers to:

1. Typological identity, which describes the equivalence between ecosystems that share the same interacting key variables. It refers to the type of ecosystem and is fundamental for the existence of the system.
2. Numerical identity, through which the system maintains its key variables and their interactions within spatiotemporal continuity.
3. State identity, where state stands for a particular situation of the system at a given moment. State identity is also specified through two different components:

3.1. Local state identity, in which the values of key variables remain near the equilibrium.

3.2. Global state identity, in which the key variables can move away from the equilibrium, but without crossing the thresholds (p.3148-3149).

Identity is often cited in definitions of resilience, as will be specified in the next subsection, and helps identify the main traits of the system, so that they can be analysed across changes.

From the point of view of functionality, "ecosystem function" is a term with various interpretations. "Sometimes, the concept is used to describe the internal functioning of ecosystem (e.g. maintenance of energy fluxes, nutrient (re)cycling, food-web interactions), and sometimes it relates to the benefits derived by humans from the properties and processes of ecosystems (e.g. food production and waste treatment)" (De Groot et al., 2002, p.395). Therefore, there is an internal or external functioning of ecosystem, corresponding to functions for itself or for human use, which are grouped and described into four primary categories:

1. Regulation functions: the ones that regulate essential ecological processes through bio-geochemical and biospheric processes. They sustain ecosystem health and human health, directly or indirectly, through services like clean air, water and soil.
2. Habitat functions: ecosystems serve as refuge to animals and plants, conserving biodiversity.
3. Production functions: the ones that are connected to flow of energy and matter through food chains and food webs.
4. Information functions: ecosystem maintain a reference function for the health of human beings, who address nature for reflection, recreation or aesthetic experience.

The chosen order has a hidden logic, placing the first two as essential for preserving natural processes and components. These first two function groups are fundamental for the sustaining of the following two. However, the given order should not be followed strictly, because human life largely depends on every function group (De Groot et al., 2002, p.395-396). In general, in the ecosystem there are various groups functioning simultaneously, which are referred to as ecosystem multifunctionality (Song et al., 2014, p.87). Since functions are dynamic, multifunctionality is more than simply the sum of them.

Successively, there are different products and ecological services that are implied in the functioning of ecosystems as well, for which resilience is important, because it keeps their activity. Services are provided by all ecosystems and are fundamental for the planet and everyone who lives on the planet. Services are grouped in provisioning, regulating, supporting and cultural services, reflecting the meaning of the functions previously introduced. Specifically, regulating and cultural services recall the corresponding functions, while provisioning services are linked to the generation of products to maintain the health of the ecosystem, and supporting services provide the foundation of all the other services. Functions are related to natural properties of ecosystems, while services are linked to human use of ecosystem functions for themselves.

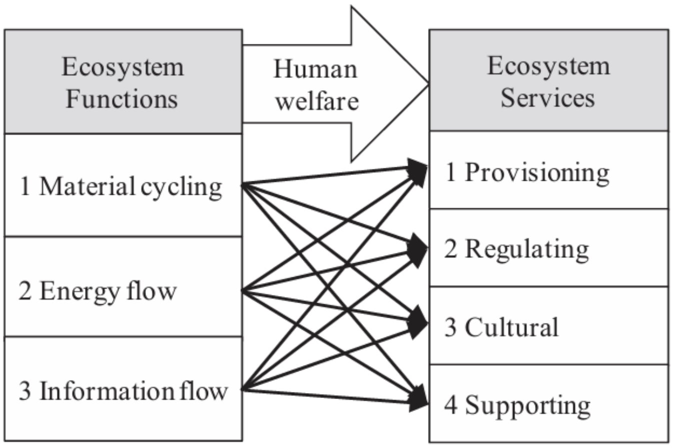


**Figure 1. Multiple correspondences and interrelations occur between functions and services (Song et al., 2014, p.88).**

These services are essential for human life, but "they do not maintain those conditions in order to preserve the world for *Homo sapiens*; rather, *Homo Sapiens* exists because those conditions permit it to do so" (Levin, 1999, p.8). Natural capital and man-made capital are considered complementary to enhance sustainability, and these two capitals need to interact constantly. Critical natural capital emerges from this interaction, and it underlies "the part of the natural capital that performs important and irreplaceable environmental functions, i.e. ecosystem services that cannot be sustained by other types of capital" (Brand, 2009, p.605). Furthermore, natural capital, with the plurality of various stocks it represents, must be preserved for the quality of life of our and future generations.

The concept of natural capital can be explained according to different domains, such as socio-cultural, ecological, ethical, economic or concerning sustainability and human survival. Depending on the chosen domain, natural capital is variously nuanced, for example, the ecological point of view values the uniqueness and the biodiversity, while socio-cultural emphasizes peculiarity of a social group, such as health, recreation or cultural identity (Brand, 2009).

The concept of natural capital enables us to explain the link between resilience and sustainability, viewing resilience as a component of strong sustainability.

## 1.2 Resilience in ecosystem ecology

The word “resilience” originates from “resilire”, a Latin term which means “rebound”. The concept is polysemic and it is widespread in several domains. In this chapter it is analysed according to the ecological field, firstly considering its uses among ecology studies through an historical perspective. In past decades there have been different definitions and uses and of this concept in ecology, which have gradually led to a better understanding of the mechanisms underlying ecosystems facing disturbances (Ingrish and Bahn, 2018, p. 2). In addition, researchers have increasingly expressed the need to create a common language for resilience, in order to share common knowledge and have a better understanding of the concept, helping to find main features of resilience in every situation (Ingrish & Bahn, 2018, p. 2, Brand & Jax, 2007, p.1).

Holling was one of the first researchers to studying and define resilience in an ecological context, exerting a considerable influence on following work. He originally stated that “resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist” (Holling, 1973, p.18). This definition aimed to consider resilience as a property of ecological systems, in order to describe their behaviour, but “did not recognize that resilience sometimes requires adaptation or transformation” (Lade et al., 2020, p.3). In fact, Holling referred to absorbing and persisting, without underlining the changes that could be made through the systems.

Later, Holling distinguished between two complementary ways of defining resilience in ecological literature. One is “engineering resilience”, which “concentrates on stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property” (Holling, 1996, p.33). This type of resilience focuses on efficiency, constancy, and predictability, and it is characterized by high persistence, resistance and rapid return to equilibrium after disturbance, which usually is small and temporary.

The second is "ecological resilience", in which its measurement "is the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour" (Holling, 1996, p.33), highlighting persistence, change, and unpredictability. In this case, the disturbances faced are stronger and can be permanent.

The view of "ecological resilience" is better suited for the analysis of ecosystems, because "that interplay between stabilizing and destabilizing properties is at the heart of present issues of development and the environment" (Holling, 1996, p.33). In nature there are different stable states, and their limits are tested by variations. Ecological resilience increases when the instability maintains diversity and persistence, granting the functioning of the ecosystem. In fact, stability is a characteristic that is not always desirable, for example, because it does not support evolution (Adger, 2000, p.349).

In later studies, an extended ecological definition was developed focusing on the maintenance of crucial structure and key processes of the ecosystem, and therefore on ecosystem identity. For example, resilience is presented by Delettre (2020, p.1) as "the capacity of a system to persist in face of disturbance", where capacity implies something that "can be present without manifesting itself". Another term employed in this definition is "persist", which can be explained by the idea of maintaining the identity of the system, in its different facets. The metaphor of a ball moving through a landscape is a representation used to link resilience to the concept of typological, numerical and state identity, as described in the previous subsection.

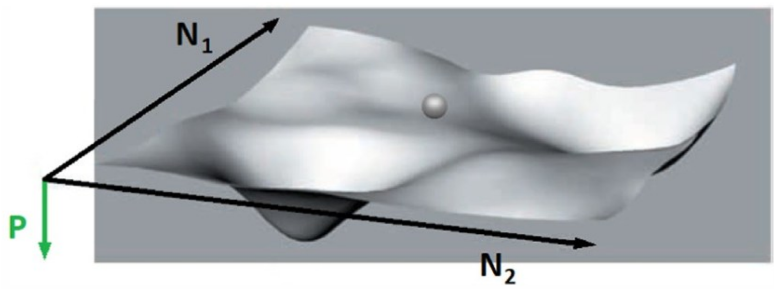


**Figure 2. Dimensions of the Stability Landscape (Delettre, 2020, p.3149)**

In Figure 2, the dimensions N1 and N2 represent a key variable (typological identity), and according to them, the position of the ball explains their value at a given time. Dimension P represents the potential of the system, which depends on the interaction between N1 and

N2, and, in this case, the position of the ball illustrates the system stability at a given moment. The landscape describes all the possibilities according to the key variables of the system, while the ball stands for its current situation and both are defined by internal and external conditions. Considering ball position, it is possible to analyse the facets of system identity in a certain situation. The shape and the limits of the landscape represent numerical identity, implying continuity in the movement of the ball inside the landscape, but without crossing the limits, because numerical identity peculiarity is spatiotemporal continuity. State identity is represented by more (global state identity) or less (local state identity) enlarged zones of the landscape.

Following this model, resilience has been defined as "the capacity of an ecological system to maintain its local state identity in the face of disturbance" (Delettre, 2020, p.3151), referring to the engineering resilience of Holling, rapid recovery and resistance. On the other hand, the ecological resilience of Holling is referred to as the maintenance of system global state identity.

These definitions can also refer to the ability to cope with disturbances without crossing thresholds and changing the state of the system, while keeping the variables close to the equilibrium point or trajectory. In this case, to enhance resilience, it is necessary to identify the tipping points not to cross, which also allow the system to discover the attributes that make it resilient. Tipping points are critical limits and crossing them cause important effects in irreversible changing. Even by restoring the previous good conditions for the existence of the system, it could not be possible to return to the previous structure of the ecosystem.

Another similar conception of resilience, more focused on measurement, considers resilience as the distance of a given population from the tipping point (Campantico & Varrone, 2024). This can also lead to the identification of the key variables which need to be protected to preserve and increase resilience.

Moreover, Carpenter identified three main properties of resilience in ecological systems (Carpenter et al. 2001, p.766):

1. The amount of change the system can face until it shifts domain of attraction, changing its state.
2. The capability of self-organization.
3. The capacity to learn and adapt.

Firstly, he recalled the conception of identity and evolution facing disturbances, and then he highlighted other two essential capabilities which support this change: the degree of self-organization and the degree of learning and adaptation (Brand & Jax, 2007).

Therefore, resilience always concerns adaptation, reorganization and change as fundamental features while facing perturbations. For this reason, it should not be associated with the conception of "bouncing back", but to the fact that it "is all about changing in order not to be changed" (Walker, 2020, p.1). The system responds through a reorganization of its parts and the interaction between them, so that its functioning changes, but not its state. In this way, a system can learn from experience, becoming able to cope with disturbances similar to the ones already experienced. To achieve this goal, the system does not bounce back behaving as it did before, but it changes its actions. As a result, another characterization of resilience can be summarized by "guiding not steering" (Walker, 2020, p.2), giving the possibility to learn where not to go rather than following a preferred state. In this way, resilience is considered more likely to offer direction and explore limits by letting the system build an acknowledgement of its own possibilities.

Transformation is complementary to resilience, because a resilient system knows "when an unwanted transformation is inevitable and instead deliberately [transforms] all or parts of the system such that the new system delivers what is valued and wanted" (Walker, 2020, p.2). Considering that the system can have different stables states, as Holling stated, it can shift its regime, looking at its conservation and not just at the maintenance of its state identity. This possibility is referred to as meta-regime resilience by Delettre (2020).

In this way, the system can persist if it remains in the stability landscape while shifting to another basin of attraction. At the same time, the numerical identity would be maintained, because the nature of key variables would not be affected, as well as their interactions. Finally, the consideration of different possible regimes is associated with the adaptive capacity and typological resilience.

Some researchers emphasize the concept of alternative stable systems, which exist within alternative basins of attraction. In fact, four aspects are underlined as essential for the description of a basin of attraction (Brand & Jax, 2007, p.4):

- Latitude, which defines the highest amount of change that can be made by the system still being able to recover and refers to the total area of the attraction basin.
- Resistance, which stands for the degree of difficulty of changing the system.
- Precariousness, or the proximity to a threshold.
- Cross-scale relations, which influence the previous three points.

Based on these items, it is possible to deduce that high latitude and low precariousness allow the system to achieve engineering resilience.

For the analysis of resilience, according to "cross-scale relations", it is necessary to go beyond the scale of the perceived problem and to cope with the managing of multiple scales, considering both the particular parts and the general configuration. Even for resilience itself it is important to build a general development, concerning different parts of the system and all kinds of difficulties. Focusing on a restricted cause or feature can reduce resilience, because it does not consider the complexity of the system.

Resilience has increasingly been associated with the concept of sustainability, becoming a boundary object and concerning the more general perspective of social-ecological systems. Therefore, its analysis has been extended to the interactions between social and ecological factors, as will be specifically explained in the third chapter.

## 1.3 Disturbances and stress

Different terms are used in the field of ecological research to define a given sort of adversity that every system must face. This concept is addressed by words such as perturbation, stress, hazard, threat or shock, where, for example, "perturbation" highlights the major spike in pressure and "stress" refers to a continuous or slowly increasing pressure. Usually stress originates within the system, while perturbation has an external origin, although not exclusively.

Disturbances can be differently originated because they can be driven by natural processes, for example, in the case of wildfires, or by human activities, such as deforestation. Disturbances do not belong to the system, and they are the basis for resilience, because they interfere in system activities and stimulate responses from them. "Disturbances can cause transient changes in ecosystem properties and processes or even lead to a complete reorganization of an ecosystem by causing a shift to an alternative stable state" (Ingrish & Bahn, 2018, p. 2). Reactions to disturbances can vary according to different characteristics of the disturbance, such as strength, frequency, intensity, spatial and temporal pattern. In any case, ecological systems have developed naturally the ability to respond rapidly to shocks and changes.

On the other hand, environmental stress is regulated by abiotic factors, which can enhance or affect the stability of an ecosystem, such as climate and resource availability. For example, rainforests are more stable and grant low stress to organisms through fewer changes. This is due to optimal climate conditions, that ensure humidity and warmth enhancing biodiversity. In general, "stressful environments are best defined as those in which producers are limited by the environment in their ability to convert energy to biomass, and it is under this focus on productivity that most community ecologists examine stress" (Maestre et al., 2009, p.200).

Considering the community level, stress does not concern only the individual, because it can be enhanced or reduced by the quality of interactions between organisms or species. In this sense, the stress-gradient hypothesis is a theory that has been developed about species interaction in plant communities, increasing the consideration of facilitating interaction, which originally was ignored preferring competition as fundamental mechanism of community organization and resource partition Brooker and Callaghan, 1998). Facilitation describes cooperation between plants, which can be developed in a relationship of mutualism or altruism. Mutualism occurs when positive outcomes concern both plants, while in the case of altruism a plant benefits from the interaction and the other cooperates with a negligible cost (for example limiting its growth), but can still benefit from an improved environment. These are both active strategies and differ from other strategies such as the neutral one, where plants benefit from avoiding unnecessary competition for resources. In any case, interaction is positive because at least one individual benefits, while the other remains unaltered (commensalism) or benefits too (mutualism).

Returning to the stress-gradient hypothesis, the rates of competition and facilitation within the community vary according to physical stress or ecosystem productivity. "Just as the importance and intensity of competition seem to decrease with increased disturbance, so positive interactions seem to become more important and intense" (Brooker & Callaghan, 1998, p.199). Dynamics of competition and facilitation also depend on species traits such as "stress tolerance and competitive ability of the interacting species" (Maestre et al., 2009, p.200). Considering this distinction, the probability of survival is higher for the stress-tolerant plant rather than the competitor plant, and the same applies to the growth of these species, even though growth rates are generally lower than survival rates throughout difficulties. Following the stress-gradient hypothesis, high abiotic stress and high consumer pressure enhance facilitation between different species, bringing positive interactions. This is due to concentration of selective forces on surviving the severe conditions, rather than winning competitive interactions. For example, the treeline protects itself, with trees in this transitional area that grow together and are more efficient in protecting each other from difficulties, such as cold winds or excessive snow that covers them, rather than competing. In this way they are likely to mitigate and improve the environmental conditions they live in, because these increased difficult conditions are responsible for cooperation for the survival of every individual, while favourable conditions would lead to competition within the group of plants.

Nevertheless, the characteristics of stress need to be considered. For example, resource-related abiotic stress may lead to competition when facilitator and facilitated species both need the same limited resource (water, light or nutrients). In this case, facilitation occurs if it can improve the availability of the disputed resource. However, if the conditions are exceptionally stressful, the severity of external environment increases and the facilitation between species may diminish, given the incapacity to help stress-intolerant plants to survive or grow.

Finally, another important feature connected to ecological resilience and difficulties is the tendency to operate at the edge of instability. Indeed, disturbances and instability are seen as opportunities, requiring flexibility and efficient control of internal dynamics, in order to generate external options (Holling, 1996). In this sense, the researcher Vacchiano (2029) represents stress as a "sieve for mutations" (p.42), retaining and stabilizing only the most useful characteristics for surviving a given environment. Stress challenges system, but at the same time it allows biotic component to always form an "engine" of infinite variety. Consequently, exposure to disturbances enables the systems to keep being resilient, in an ecological and transformational way. Otherwise, if they are always protected, they will lose their tolerance to stress. This reflects the possibility of exploring the boundaries without crossing them, but if the difficulties are too intense, the limits can be crossed, and the system can be damaged. Even the frequency of disturbances is particularly relevant. For example, the rapidity and the powerful effects of climate change could lead to dramatic consequences on ecosystems in the case of the alteration being faster than the adaptation.

### 1.3.1 Vulnerability

Stresses and disturbances are linked to the concept of vulnerability, which can be variously defined in relation to different dominions, but, generally, is composed by "exposure to perturbations or external stresses, sensitivity to perturbation, and the capacity to adapt" (Gallopin, 2006, p.294). In the case of natural ecosystems, vulnerability "can occur when individuals or communities of species are stressed, and where thresholds of potentially irreversible changes are experienced through environmental changes" (Adger, 2000, p.348).

Analysing the relationship between ecological resilience and vulnerability, it emerges that these terms are not antonyms but can be considered complementary measures of stability. Furthermore, a word like "robustness" would be better suited as antonym of vulnerability, because its meaning underlies the maintenance of a structurally stable system against disturbances, without changing, even if the limits of its resilience are reached. "For some, the fundamental distinction between vulnerability and resilience lies in that vulnerability refers to the capacity to preserve the structure of the system while resilience refers to its capacity to recover from non-structural changes in dynamics" (Gallopin, 2006, p.295). Therefore, vulnerability can be restricted to cases of structural change in the system, but a deeper analysis of the situation is required to understand if the change is structural rather than behavioural.

Furthermore, similarly to resilience, vulnerability declines according to the perturbations, so that some perturbations can involve vulnerability, while others cannot. Every disturbance can have a different effect on the system and vulnerability does not necessarily have a negative meaning, for example in cases of beneficial transformation, exactly as resilience is not always positive.

Sensitivity is another concept involved in facing adversities, and, generally, refers to "the degree to which the system is modified or affected by an internal or external disturbance or set of disturbances". (Gallopin, 2006, p.295). Sensitivity and vulnerability are also related to exposure, which is given by the interaction between the system and the perturbation and stands for the intensity or the duration that qualify the experience of disturbances. Furthermore, exposure can be connected to vulnerability following an internal or an external perspective. In the first case, exposure is considered a component of vulnerability, which depends on the interaction between the disturbance and the system, and which quantification would require considering all the possible situations, because vulnerability changes according to exposition. On the other hand, if exposure is referred to as external from vulnerability, vulnerability becomes a property of the system and emerges when facing disturbances. In this case, vulnerability exists prior to the disturbance but is influenced by previous experiences of perturbation of the system, a principle that also applies to resilience.

## 1.4 Equilibrium and adaptive capacity

"Equilibrium is the steady state of an ecosystem where all organisms are in balance with their environment and with each other" (LibreText, 2022, 46.1A). This steady state is compromised when a change occurs, but it reaches a new balance thanks to negative feedback. In the case of ecosystems, the equilibrium is always dynamic and never static, through the continuous reorganization of every component. The dynamic equilibrium of the ecosystem towards a better stability is nourished especially by the processes of transformation and higher biodiversity, through larger adaptability.

Different explanations of resilience in ecological systems vary according to kinds of equilibrium, where a system's response to critical conditions and changes can be smooth or sharp, leading to possible alternative equilibria in case of instability. Some definitions view resilience in a global way, referring to just one possible equilibrium to maintain or to return to rapidly, similarly to stability conception (engineering resilience). Others consider the possibility of multiple stable states, emphasizing changes and transformations (ecological resilience). The differences between these two kinds of resilience have been represented by the heuristic of a ball and a cup.

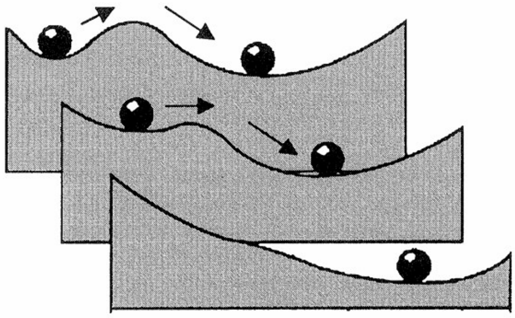

**Figure 3. Heuristic of three different stability landscapes and a ball course (Gunderson, 2000, p.427)**

"The ball represents the system state, and the cup represents the stability domain. An equilibrium exists when the ball sits at the bottom of the cup and disturbances shake the marble to a transient position within the cup. Engineering resilience refers to characteristics of the shape of the cup—the slope of the sides dictates the return time of the ball to the bottom. Ecological resilience suggests that more than one cup exists, and resilience is defined as the width at the top of the cup" (Gunderson, 2000, p.427).

Considering the landscape, a threshold is represented by the highest point between two valleys, while the arrows stand for disturbances. In cases described by one equilibrium, just one basin of attraction is represented, so that the system bounces back to the same state after a disturbance. On the other hand, different equilibria are represented by various basins of attraction, with the possibility for the system to shift to other stable states. In fact, variables of the system can fluctuate without consequences for the stability of the system beyond a certain point, then, when the threshold is crossed, there is a regime change and shift to another basin of attraction. The amount of energy required for this shift is represented by the depth of the basin.

Based on Figure 3, resilience is also individuated as the "amount of disturbance needed to push the ball over the edge of one valley into another" (Robinson & Berkes, 2010, p.336). In addition, multiple stability landscapes are represented, so that adapting capacity emerges despite the change in their shapes. Nonetheless, it is necessary to specify that the concept of stable states constitutes a simplification of reality, because it refers to systems characterized by constancy and just one state variable, while "ecological systems may have intrinsic cycles or even chaotic attractors instead of stable states" (Scheffer et al., 2015, p.148) due to interactions, interferences and randomness of fluctuations.

Finally, the concept of resilience in ecological systems is connected to equilibrium, but in a different way from the concept of resistance. In this sense, resistance is disconnected from renewal, reorganization and development despite the presence of disturbances, approaching the conception of stability. Indeed, resistance remains at the equilibrium, fighting difficulties, whereas resilience allows the ecosystem to challenge its dynamism through change. Resistance is the complementary aspect of persistence and refers to the external pressure that causes disturbance in the system. Consequently, some systems can be more persistent than others, because they are more internally resistant and can absorb more pressure.

### 1.4.1 Stability

Usually, equilibrium is associated with stability, which can be defined according to different perspectives. For example, there is a mathematical conception of the term, but it appears unsuitable for ecological systems, because they are characterized by many degrees of possibility and not by simplicity or linearity. Complexity originates from the fact that ecological systems' variables, reference state and disturbances are always differently determined according to the situation.

For these reasons, Grimm and Wissel (1997) suggested to link stability to properties like constancy, resilience and persistence in every context, clarifying its specific meaning, because using the term individually results in confusion, leading to various meanings. Indeed, considering the complexity of systems, stability is a contextualized concept that can only be declined focusing on a specific situation, which needs to be clearly identified. In this regard, Grimm and Wissel introduced an "ecological checklist" to better describe the stability of an ecological situation, finding its characteristics. The six features listed include: level of description, variable of interest, reference state or reference dynamic, disturbance, spatial scale and temporal scale. Finally, they also stated that stability should be connected to reality and should not be generalized or referred to as hope for a better ecological state.

Another important distinction to make is the one between "resilience" and "stability". As we have seen before, Holling referred to resilience as a property of the system, where the system can "absorb changes of state variables, driving variables, and parameters, and still persist" (Holling, 1973, p.17). On the other hand, stability "is the ability of a system to return to an equilibrium state after a temporary disturbance" (Holling, 1973, p.17). Stability is also a property of the system in this definition, and the result is given by the fluctuation around the equilibrium: the rapidity of return to equilibrium and the quantity of fluctuation describe higher or lower stability of the system. As a result, stability can be measured by the recovery rate toward equilibrium.

Resilience and stability can combine in ecological systems, so that one can be very persistent, while the other being low and vice versa. For example, in areas subjected to severe climatic conditions, the ecological system's behaviour would be more persistent and resilient, but with reduced predictability and stability due to the higher fluctuation. Finally, "the balance between resilience and stability is clearly a product of the evolutionary history of these systems in the face of the range of random fluctuations they have experienced" (Holling, 1973, p.18).

Indeed, the entire Earth functions as a system, with its regularities, like a sort of superorganism. This approach is supported by "the theory of Gaia", conceived by Lovelock in the 1970s. In particular, the theory of Gaia interprets the biosphere as animate and explains how it maintains its stability. Indeed, systems contribute to shaping the environment and their evolution over time has formed the complex self-regulating system in which we live in, engaging in the maintenance of homeostasis. The Earth is a living system characterized by physiological processes that regulate its temperature and chemical composition to maintain favourable conditions for life. In this sense, the Earth can intervene on changes or sources of disturbance, in order to efficiently rebalance living conditions. Evolution represents the basic force promoting life, in which variation plays a key role through an endless process of change and adaptation with progressively better suited solutions.

### 1.4.2 Adaptive capacity

Starting from adaptation in the ecological context, "becoming adapted" stands for pursuing the capacities of survival and reproduction, which are the two fundamental instincts of all living organisms. The adaptation is multifaced and shaped according to morphological, physiological and behavioural change.

It is necessary to distinguish the meaning of adaptation from other connected conceptions. Indeed, adaptedness and adaptation are different features. Adaptedness refers to specific situations where different species are adapted to different environments, while adaptability describes the capacity to adapt and react to changes in their environment or in other environments. Moreover, adaptation differs from adjustment, because adjustment does not change the system itself, unlike adaptation, which can develop the system into a new state. A further distinction concerns adaptation and mitigation, because mitigation has an external focus, consequently, actions target the source of disturbance, rather than the system itself.

One of the dimensions of resilience is adaptive capacity, which, in biology, is the "ability to become adapted to certain range of environmental contingencies" (Gallopin, 2006, p.300), evolving "through innovation and learning mechanisms" (Delettre, 2020, p.3153). Basically, systems do not tend to stability or equilibrium but evolve following the conception of the "adaptive cycle", which is composed of exploitation, conservation, creative destruction and reorganization. The first phase is characterized by rapid colonization and growth, then, material and energy are stored in the second phase. These two phases together describe ecosystem succession and shape the structure of the ecosystem, which becomes very stable, but at the same time brittle.

Subsequently, a perturbation occurs, initiating a collapse and leading to the destruction of the system. In this case, disturbance is very strong, while persistence is low. After destruction, the cycle connects to another following cycle based on the renewal and reorganization of the system, allowing better adaptation and persistence in regard of disturbance. In this last phase of the cycle, the stability is low, so that the system can move to a different state, opening to novelty, with new possible species that can emerge. Here, resilience addresses both to change and ecological memory, connecting to the historical component of resilience which "determines the capacity of ecosystems to reestablish their former functions and avoid phase shifts following disturbance" (Lundberg & Moberg, 2003, p.89). In particular, ecological resilience is maintained through the cycles by focusing on the key cross-scale processes and interactions, rather than considering a single mechanism.

Even in catastrophes it is possible to find rebirth, because there is always something left that turns into nourishment, energy or protection, and from which it is possible to re-start the system. What remains after the disturbance constitutes the internal ecological memory and is composed by "surviving organisms (residuals), organic materials, and the organically generated environmental patterns that persist through a disturbance and serve as foci for regeneration and recolonization" (Lundberg & Moberg, 2003, p.89). For example, this occurs when a forest destroyed by fire recovers through secondary succession. In fact, the area is recolonized and pioneer species spread quickly because the area is very rich in nutrients. Foundation species are the base of the community, they bring energy essential for life, creating the conditions and the environment for the community to exist. Furthermore, through the renewal, biodiversity is enhanced because new species emerge, with different options for development of the system.

Ecological resilience would seem to characterize only the first two phases of the adapting cycle, where the aim is to maintain typological identity, while in the third phase instability prevails, leading to possibly losing and changing typological identity, as well as all the other identity facets. In the sense of evolution, adapting capacity becomes more important and efficient than resilience, relying on keystone processes, reformation and functional biodiversity. Finally, if the disturbance occurs periodically, causing various adaptive cycles, the disturbance itself becomes an internal factor and a key variable of the identity system, relying on ecological resilience. For example, some studies demonstrated that the Fagus tree has adapted to fire destruction by increasing the production of seeds when fire occurs. These trees are able to perceive the climate conditions that could lead to a fire, so they overproduce seeds, which have increased possibilities to grow after the fire. Indeed, fire destruction enhances the birth of new specimens because fire destroys obstacles that block sunlight from reaching the seeds in the soil, which are nourished by the ashes of burnt leaves (Vacchiano, 2019, p.32-33).

Typological resilience is concerned in the adaptive cycle, referring to the maintenance of typological identity of the system. According to Delettre (2020), typological resilience is a type of resilience, together with meta-regime, ecological and engineering resilience. These declinations of resilience are differently considered according to the strength of perturbation and persistence, which are inversely proportional.

## 1.5 The role of diversity

Higher rates of diversity in an ecosystem increase the complexity of the system, especially from a functional perspective, connecting biodiversity, ecosystem services, functional groups and response diversity. Disturbances and unpredictability are at the basis of diversity renewal, maintaining species in the system.

### 1.5.1 Biodiversity

"Biodiversity can be described as the diversity of life on Earth" (MEA, 2005, p.1), referring to a complex concept that "has many components—including the diversity of all organisms, be they plants, animals, or microorganisms, the diversity within and among species and populations, and the diversity of ecosystems" (MEA, 2005, p.1). It is possible to decline biodiversity according to species' richness and evenness, where richness describes the quantity of different species, and evenness describes the quantity of individuals for each species. Considering community and species level, diversity refers not only to the existence of different species on our planet (interspecific diversity), but also to the differences within species, which are referred to as intraspecific diversity or genetic diversity. Heterogeneity, through genetic variability, is essential for the flexibility necessary to face changing environmental conditions, because individuals become tolerant of different disturbances. Furthermore, genotypic and phenotypic variation enhances populations' fitness and efficiency in response ability, for a healthy ecosystem which is maintained by general high interspecific and not just by an intraspecific diversity.

Another dimension of diversity is the heterogeneity of ecosystems, referring to landscapes. This kind of diversity promotes spatial resilience in ecological systems helps coexistence of species with the same functionality by reducing competition. There are different patches in the ecosystem that have different levels of tolerance to pulse disturbances (sudden, discrete, and relatively short-term events), and some of them can remain undisturbed, constituting refuges for the organisms. Starting from these safe places, it is possible to recolonize and reorganize the disturbed areas, through ecological memory and the contribution of species that have mobile link functions, which can bring external ecological memory. At a larger scale, this mechanism of protection and renewal could be applied also in responding to climate change, which is composed by series of pulse disturbances, such as fires and droughts.

In addition, biodiversity can change depending on time and place, so, when analysed, the location and the level of biological organization (such as populations, species or ecosystems) must be precisely specified. Looking at this complexity, it is not possible to define overall biodiversity focusing on just one component, especially since every element varies independently of the others.

In synthesis, intraspecific, interspecific and ecosystem diversity are the main mechanisms that compose biodiversity, and they are all connected and interdependent to maintain ecosystem resilience. An approach that focuses on landscape heterogeneity "is likely to be the most effective strategy in conservation, because preserving biodiversity at a landscape level is likely to simultaneously ensure metapopulation genetic diversity, secure high functional redundancy and response diversity, and preserve ecological memory" (Vasiliev, 2022, p.5).

The evolution of the concept of biodiversity is of particular importance in the context of global environmental change. Studies value biodiversity, emphasizing the interdependence of species and their interaction with abiotic elements. Biodiversity is essential for our lives, because it maintains an environment propitious for human existence as we know now (Levin, 1999, p.4). It is important to enhance biodiversity, knowing that extinction is irreversible:

"the evolutionary history and biological resources embedded in each species are permanently lost when that species is lost" (Levin, 1999, p.5). Today the extinction of species is rapid and abundant at global level and is destined to increase progressively in the future. The effort to preserve some species by isolating few members does not solve the problem, because populations and diversity disappear, reducing the services provided by the species and affecting ecosystem services and functioning. The loss of a local population has influences on the neighbourhood, causing other losses and reductions, implying a progressive transition from a local to a global level. The cumulative effects of species loss result in the greatest impact, because even interactions between species decrease, by reducing the possibilities for mutualism. There are consequences for all species, because also the species which are not menaced by extinction decline in their abundance as a result.

Biodiversity loss is defined "as the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels" (Convention on Biological Diversity, 2005, p.1300). The loss of biodiversity can be led by a reduction in diversity of species, through extinction, or a reduction in the possibility of species providing a particular service. Other drivers of biodiversity loss are habitat change, climate change, overexploitation, pollution and the process of homogenization given by the spread of invasive alien species. These new species vary homogenization through their aggressiveness and the services they bring or damage. Furthermore, homogeneity is also produced by the extinction of unique species located in particular places.

The current extinction of species is giving rise to predictions regarding the future that highlight the copious growth of extinction in comparison to the past, as represented in Figure 4.

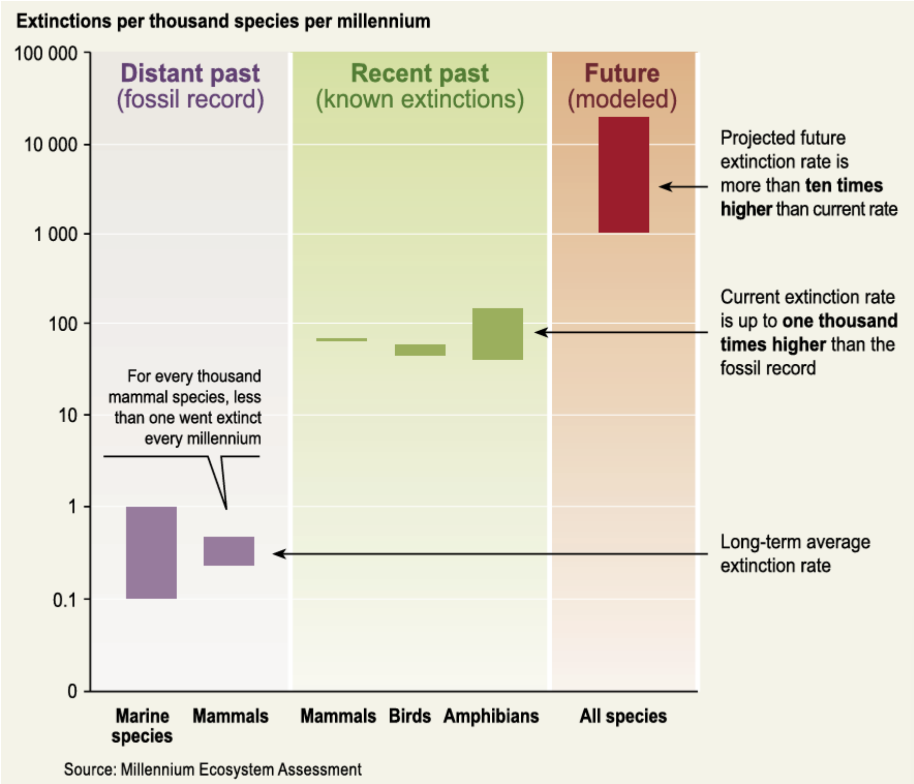


**Figure 4. Species extinction rates throughout the time (Millennium Ecosystem Assessment, 2005, p.4)**

The growth of extinctions is described by upward steps, and each one represents a tenfold increase over the previous level, declining an important acceleration in the future. Here the future can only be projected, so that the estimates are hypothetical, even if they are based on a variety of techniques, such as species-area models, rates of species shift towards higher threatened categories, habitat loss and extinction probability.

There is a strong connection between biodiversity and ecosystem resilience: by examining the way they are related it is possible to deduce that "the more homogeneous the environment in space and time, the more likely is the system to have low fluctuations and low resilience" (Holling, 1973, p.19). Thus, variability of means and properties of the ecosystem over time and space (temporal, spatial and spatiotemporal insurance) is an important factor increasing resilience and stability for ecosystem functionality, as affirmed by biological insurance theory, which considers two main effects:

- "Buffering effect, i.e. an increased temporal stability or reduced variability of aggregate ecosystem properties that arises from species' differential responses to environmental variations" (Loreau et al., 2021, p. 2334).
- "Performance-enhancing effect, i.e. an increase in the mean level of ecosystem properties, which occurs when the best performing species are favoured under each

environmental condition" (Loreau et al., 2021, p. 2334). In the same way, selection effect operates by advantaging the best features, which "drive" the system while still maintaining biodiversity at larger scales by balancing it with functional complementarity, because each species can be better suited to various conditions changing in time and space and diversity ensures the availability of more species characteristics. Asynchrony and dispersal can support this complementarity, because species are distributed across time and space, and may be best suited in response to certain conditions at a given moment and place, thereby fulfilling their role.

Species richness is one of the most considered factors, and studies of functioning show that several species perform better than monocultures. This is due to their functional traits and intraspecific variation, which are two different ways of measurement.

### 1.5.2 Functional diversity

Functional diversity is an important component of biodiversity and involves "the value, variation and distribution of traits in a community assembly" (Song et al., 2014, p.85). It can be measured in individuals or communities, but generally it is considered at species level, specifying interspecific differences. As with the constitution of species diversity, functional diversity is composed of functional richness, evenness and divergence.

"Functional richness measures the present species occupying the amount of niche space within an assemblage, functional evenness measures the distribution of species traits occupying the trait space, and functional divergence measures the maximum degree of divergence of abundance distribution of functional trait in trait space within an assemblage" (Song et al., 2014, p.86). Based on this principle, the functional richness is higher if various species have different characteristics, while the functional evenness is higher if species traits are more distributed in the area. Finally, functional divergence is higher if abundant species traits are more extreme.

Functional diversity is a fundamental feature for the system and better explains its functioning than species richness, because functional diversity includes redundancy, which increases the functioning of the system. Functional redundancy — "that is, the existence of multiple species that fill similar ecological roles" (Levin, 1999, p.8) — preserves the functioning of the biosphere, giving alternative ways to face disturbances and promoting evolution, because the shifts within the system have reduced effects on system processes. Homeostasis is the condition that defines this state of stability, aimed at finding a fluid inner balance: in this sense, resilience in an ecological context can be considered a homeostatic feature.

Moreover, functional diversity "provides great robustness to the process and, as a consequence, great resilience to the system behaviour" (Holling, 1996, p. 40). This is enhanced by the diversity hypothesis, in which high species diversity leads to a more efficient use of the resources, according to the needs and traits of every species. The other mechanism is mass ratio hypothesis, where ecosystem functioning is controlled by dominant species traits in a disproportionate way, because these species require more resources than others.

In addition, functional diversity is related to functional redundancy, although they have different implications since the first one "arises when different species that perform a similar function exploit different aspects of a habitat" (Leslie & McCabe, 2013, p.3). On the other hand, functional redundancy, or ecological redundancy, is explained by the fact that many species may perform the same function, such as pollination, seed dispersal or short-grass grazing. Consequently, each species plays its role and faces disturbances and variables in a different way from the others, which is important for preserving ecosystem structure and functions. Every species has a niche within the ecosystem, which signifies that every species has a unique way of using its environment, referring to the conditions, resources and interactions it requires. Furthermore, the importance of every component of the ecosystem must be acknowledged, recognizing the numerous interrelations between them for the survival of the whole groupment.

Considering differences between roles, species living in the ecosystem can also be categorized into "drivers" and "passengers". Drivers are represented by keystone species and can alter the system, controlling its future evolutions. The structure of ecosystems is regulated by the keystone species, which provide stability to the system, maintaining the environment. Mobile link species also contribute to resilience, allowing better recovery from difficulties. In fact, they connect different parts of the ecosystem enhancing ecological memory and contributing to fundamental functions like pollination, seed dispersal and translocation of nutrients. On the other hand, passengers do not have control over the system but simply live in it. In this distinction, drivers have a greater impact on the system and they enhance ecological resilience, especially if their group is characterized by greater diversity.

High functional redundancy can sometimes hide vulnerabilities of the group which can subsequently lead to low multifunctional redundancy and trait-based redundancy. Low multifunctional redundancy involves the compensatory dynamics between species by response diversity and species asynchrony, which refers to alternating species dominance or dormancy throughout time. The successive evolution of low redundancy determines that the number of species is related to the number of functional contexts, including environmental variations in time and place, and is referred. For this reason, it is important to specify the context and its conditions to define the active or dormant functionality of the species. Trait-based redundancy declines according to biogeochemical attributes, morphology and physiology of species. However, these aspects are not subject to variability in time and space, resource use or niche peculiarities. On the basis of trait-based redundancy, some species can be considered redundant in a period, because they do not respond to functionality for that instance (dormancy), but at a certain point they start contributing again. For both low multifunctional redundancy and trait-based redundancy, these species important, despite the intermittence between dormancy and dominance. Furthermore, phenotypes and species traits can acclimatize, which means they vary according to environmental characteristics and generally they respond to changes in the environment. The physical environment presents resources and constraints, which shape the appearance of living organisms and their strategies to survive and reproduce.

Response diversity is also concerned within the topic, acknowledging "the need for different ways for doing the same thing, with different capacities to respond to different kinds of disturbance" (Walker, 2020, p.1). Species that contribute to the same ecosystem function can face a disturbance or a change by following a range of possibles reactions, through species-specific responses according to their different abilities. Response diversity links the concept of functional redundancy and the insurance effect given by biodiversity. For example, returning to the concept of functional diversity, in a plant community, functional diversity can be represented by different species that take water from different depths or take different amounts of time to grow. In this way, each species complements the others, as insurance is ensured by response diversity, especially in face of critical conditions.

Variability in response diversity is given by external stress, which can be caused by human activity, but also internal aspects such as interspecific competition, facilitation and food-web structure. Ecosystems processes can be maintained by response diversity across spatial and temporal scales, because usually disturbances do not interfere at every scale, so that some species continue to regulate functionality. For example, coral reef grazers feed differently according to time (intensity of feeding) and space (expansion of the area), so that competition is reduced and they can all coexist while still contributing to the same function. At higher stress levels, response diversity is fragile and ecosystems processes cannot be supported by the remaining individuals. Consequently, also the space in which they act is reduced (spatial resilience) and vulnerability increases.

The effects of decrease in response diversity are not easy to fully understand, especially if ecosystem is viewed as an open system, where the limits of communities are not so defined. However, it is necessary to identify the key functions of the ecosystem in order to protect them and to focus on the parts of diversity that better cope with fluctuations and that have more influence on environment.

Finally, loss of species means that the functions and the services of the ecosystem are damaged. However, this effect is reduced from the conservation perspective, where biodiversity is a function of the system itself, and functional redundancy compensates for the extinction of species, contributing to press (continuous, long-term) disturbances. The extinction of a species can be balanced by the increase in abundance of another species that recovers its same function. Even though this is a mitigating solution, it does not mean that humans do not have to take action to preserve biodiversity, because even functional redundancy needs to be protected. In fact, if functional groups disappear and the ecosystem loses key ecological roles, the outcome is low response diversity, leading to reduced survival for all the species of a functional type. Therefore, redundancies need to be valued and protected, because they are essential for the efficiency of the system's functioning and reorganization, preserving its multifunctionality.

# Chapter 2. The dimensions of socio-psychological resilience

Social and psychological aspects represent another dimension of resilience, recalling many elements of ecological resilience, while still developing their own field-specific characteristics. Indeed, ecology and psychology are the two main fields where the concept of resilience originated and later developed across multiple disciplines and interdisciplinary connections.

Firstly, it is necessary to introduce the historical evolution of the meaning of psychological resilience. Resilience was introduced in psychology by Garmezy in 1973, through his studies on schizophrenia and stress-resistant children, which progressed in parallel with Holling's work on resilience in ecology. In particular, in his early studies of psychological resilience Garmezy focused on resistance, which referred to competence and functionality of children despite stress and exposure to high-risk experiences. He studied the way personal attributes and competence relate to the impact of stress, following compensatory, challenge and immunity models towards adaptation (Garmezy et al., 1984, p. 102-103). Here, psychological resilience was conceived as "the ability of individuals to withstand stress" (Lade et al, 2020, p.3), focussing particularly on individuals while reducing consideration of the system. Later, the perspective was broadened by involving communities rather than individuals, and by adding contextual factors. In this sense, while at the beginning psychological resilience was conceived as a personal trait, it subsequently came to be referred to as a process of adaptation.

Moreover, in the psychological field, the first analyses of resilience were based on negation, because resilience was identified in cases of the absence of psychopathology or the lack of maladaptive response. Later, it developed towards successful outcomes, adapting during or after adversities and risks. Good adaptation refers to positive behaviour according to social expectations for individuals of the same age, corresponding to succeeding in developmental tasks linked to life phases. These successes can be identified by observable achievements, such as scholastic accomplishments, or internal achievements, such as happiness. In a resilient person, good adaptation occurs even when he or she experiences stressful conditions, in line with multiple functioning, social competence and positive mental health. This highlights the possibility for the individual or group of "doing well" with respect to expectations of behaviour, nourishing human well-being, even if the effects of resilience could be negative. For example, a resilient organization may not promote individual well-being, resulting in difficulties and stress for people. Here, wellness relates to four criteria associated with good mental and behavioural health, fine role functioning in different contexts, and high quality of life, considering individual general feeling about his life.

Considering the historical perspective, it is possible to identify four phases in the evolution of resilience in psychology. These phases are dedicated to features leading to success in resilience and decline according to different objects of study, as follows (Bonanno & Diminich, 2013, p.379):

1. Measure and definition of resilience, especially considering the factors that brought positive outcomes, such as individual qualities and resources. This analysis highlighted the differences between resilient individuals and others who were overcome by difficulties.
2. Identification of protective factors only.
3. Knowledge of processes that constitute resilience, which together with protective factors develop possibilities for preventative interventions.
4. Integrative perspective that "explores moderators of risk as well as the role of neural plasticity in resilience" (Bonanno & Diminich, 2013, p.379).

Furthermore, focusing on the methodology of the studies, two different approaches can be identified for the understanding of psychological resilience conception: variable-focused models of resilience and person-focused models of resilience.

Variable-focused approaches statistically value the measurement of adaptation and the connection between individual, environmental and experiential aspects. These kinds of models are better suited for precise research, with a limited object of study, acknowledging that they simplify the complexity of real life. Additive models, interactive (or moderating) models and indirect (or mediating) models are included in this approach, and they recall those identified by Garmezy, corresponding to:

- The compensatory model, where stressors affect competence, while personal attributes contribute to adaptation.
- The protective versus vulnerability model, where protective outcomes can occur for individuals with high presence of a trait, through reduced stress level. On the contrary, in the case of vulnerable responses there is an increased stress level of individuals with high presence of a trait.
- The challenge model, where stressors can increase competence.

Person-focused approaches are more likely to follow holistic patterns because they consider the whole resilient person, with their functioning in multiple contexts simultaneously. These models can involve individual case studies, groups of resilient individuals facing higher risks, and groups of adaptive and maladaptive individuals facing lower risks in comparison to high-risk maladaptive peers.

Recent research focuses on the study of pathways, considering multiple levels over time. For example, longitudinal studies investigate continuity of psychological resilience over time, considering the changes throughout development. On this basis, Masten (2014) states that resilience can be depicted by life-course patterns describing functioning or development, as represented in Figure 5.

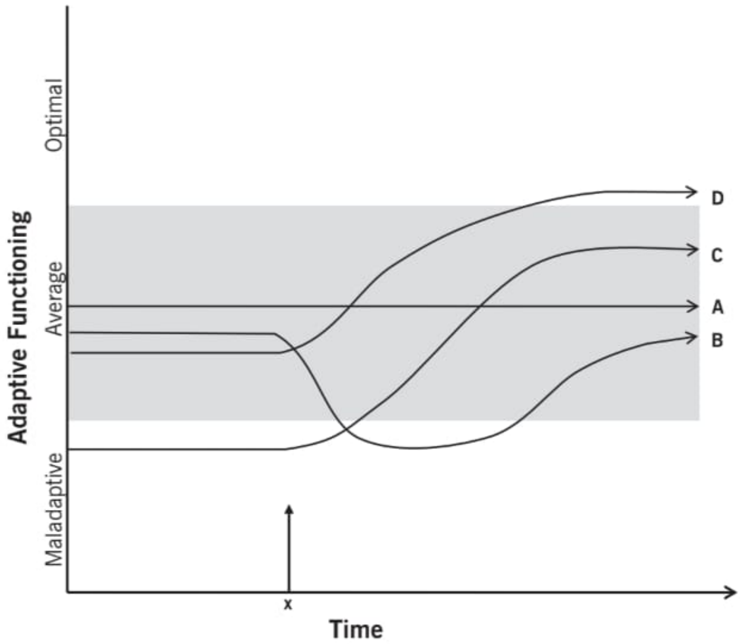


**Figure 5. Four different life-course patterns, each being influenced by an impacting adversity at time *x* (Masten, 2014, p.11).**

These patterns describe different examples of possible responses to trauma or chronic adversity: (A) stress resistance, (B) recovery, (C) normalization after reduction of trouble, (D) posttraumatic growth. The type of pattern qualifies the outcome, which can vary according to ranges of maladaptive, adaptive or optimal functioning/development.

As illustrated in Figure 5, resistance occurs without any disruption for the functioning, because resources block the difficulty, which, in these cases, is usually more predictable and less severe. Then, recovery trajectories describe progressive restoration following a long-lasting dysfunction. In other cases, resilience takes over, leading to adaptive processes that restore functioning and may result in new circumstances which differ from those prior to adversity. Finally, another possibility corresponds to the persistence of dysfunction, involving vulnerability.

The description and terminology of these processes in the psychological dominion echo those of the ecological dominion, as reflected in Figure 6.

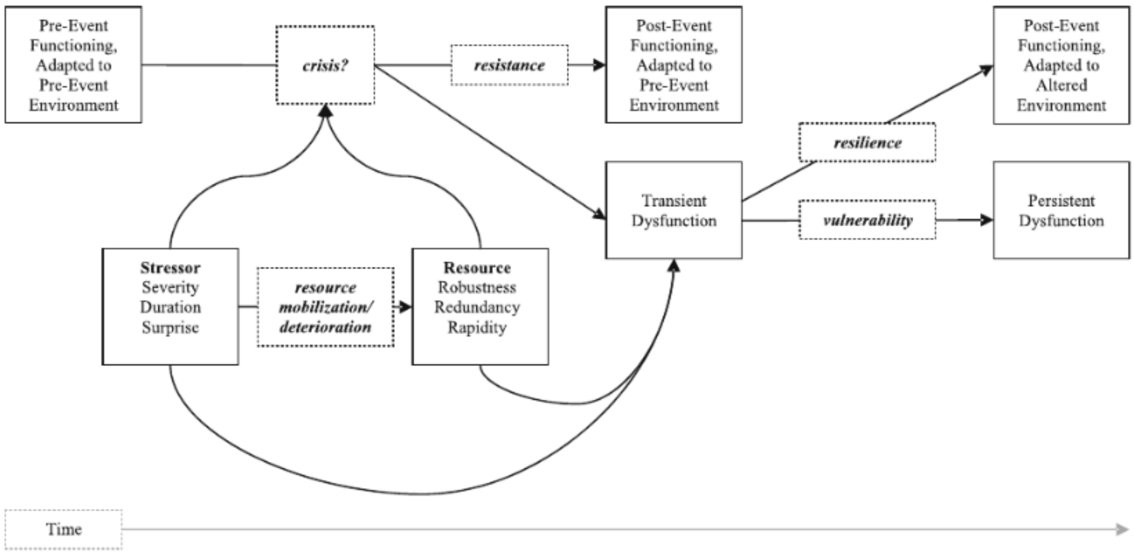


**Figure 6. Model of stress resistance and resilience over time (Norris et al., 2008, p.130).**

The model represents the passages of resilience process throughout time, illustrating resistance, resilience and vulnerability as possible pathways of functioning or dysfunction in response to stressors. The outcome varies according to different elements, regarding the source of stress or trouble and the employment of available resources, aspects that will be analysed in the following subsections.

Focusing on human responses that lead to different pathways, there are various similar process models of psychological resilience identifying an equilibrium or homeostasis of the individual, where adversities, life events and resilient factors continually interact. After the disturbance of this equilibrium, different possible responses can emerge, both positive or negative: "(1) resilient reintegration resulting in growth, self-understanding, and increased resilience; (2) reintegration back to homeostasis; (3) reintegration with loss; or (4) dysfunctional reintegration" (Tusaie and Dyer, 2004, p.5). These responses reflect and recall the life-course patterns that develop within social contexts illustrated by Masten.

In general, socio-psychological resilience is characterized by two fundamental components: exposure to risk or adversity and the following adjusting outcome. In this sense, Masten defined the resilience as "the capacity of a dynamic system to adapt successfully to disturbances that threaten system function, viability, or development" (Masten, 2014, p.10). By "dynamic system" she refers to all the possibilities, including different fields, levels, organizations and even individuals.

As a result, both psychological and sociological resilience can be better defined as processes that develop according to adaptability, rather than stability. In this way, the "ecological resilience" described by Holling offers appropriate characteristics for describing human individual or collective resilience as "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance" (Norris et al., 2008, p.130). In line with this, Keck and Sakdapolrak (2013)

> define social resilience as being comprised of three dimensions: 1. *Coping capacities* — the ability of social actors to cope with and overcome all kinds of adversities; 2. *Adaptive capacities* — their ability to learn from past experiences and adjust themselves to future challenges in their everyday lives; 3. *Transformative capacities* — their ability to craft sets of institutions that foster individual welfare and sustainable societal robustness towards future crises (p.5).

Coping capacities address the restoration of well-being through actions that follow the disturbance or are contemporary to disturbance, while adaptive capacities are also projected toward future risks, through prevention. Transformation refers to institutions, because they shape the socio-economic system and the norms that determine possibilities of social action. All three dimensions of capacities characterize every level of socio-psychological resilience, but their interaction varies according to the context.

The following sections start from an individual perspective based on development throughout childhood. Subsequently, the perspective broadens to community level and social systems. Human resilience is dealt with in terms of identifying its basic components and following the phases of the resilience process, involving risks and responses.

## 2.1 Experiencing adversities and risks

Adversities, risks and stressors are fundamental components, because they begin the process of resilience. They are all variously classified for the analysis of social and psychological resilience. For example, stressors can be grouped into three categories (Keck & Sakdapolrak, 2013, p.8):

- Natural disasters, such as floods or fires.

- Management of natural resources, considering their scarcity and environmental instability, like in cases of climate change or lack of water.
- Societal change and difficulties linked to development, for example economic crisis or migration.

Moreover, the functioning of the individual is always affected by stressors which can be connected to the normal development of the human being (horizontal stressors) or can be unexpected and harsh (vertical stressors).

Another characteristic that describes adversities is linked to temporal exposition, distinguishing single-incident trauma from chronic adversity, like war, natural disasters and parental bereavement. Emergent resilience arises in face of chronically adverse circumstances, focusing on long-term outcomes, while minimal-impact resilience refers to isolated potential traumatic events. Emergent resilience involves more significant changes and follows the evolution of time and context, so that it may be difficult to perceive. On the other hand, minimal-impact resilience refers to isolated stressors, which constitute exceptions for the normality of the usual context and correspond to acute life events such as loss or trauma. In this case, efforts to face adversities are more concentrated and targeted, reflecting the characteristics of the adversities themselves. Throughout historical progression of psychological research, emergent resilience has always been more studied than minimal-impact resilience, whose analysis is recent and still has to be developed.

In general, this distinction has produced different fields dedicated to the study of psychological resilience, which have been separated leading to the evolution of various conceptions, without integration. The diagnostic approach analyses the consequences of isolated potentially traumatic experiences, considering just two possibilities: the presence or the absence of psychopathology, such as post-traumatic stress disorder or Complicated Grief. This approach leads to lack of consideration for individual differences among people without psychopathology, focusing on health rather than resilience.

Nor can an approach based on average-level outcomes be used to define psychological resilience, because the average-level can produce a misinterpretation of the data collected, reducing and simplifying individual distinctions by finding a unique trajectory that fails to represent reality.
Therefore, minimal-impact resilience can be described by "a stable trajectory of healthy functioning before and after the event" (Bonanno & Diminich, 2013, p.382), which can be clearly observed and defined because of the restricted nature of the given adverse event. This approach examines the heterogeneity of responses and long-term consequences, which can be analysed by a set of prototypical trajectories that concern the conditions before and after

the traumatic experience. In fact, the trajectory of minimal-impact resilience describes the experience of transient distress, which does not affect the normal functioning of the individual.

Returning to adversity, there are various acute stressors and severe situations that can be experienced by children and adults. For children, common risks of this kind refer to factors linked to child status, parents, family and neighbourhood. For example, one of the gravest stressors is the loss of a parent, which should be considered as a process faced through adaptation with long-term effects. Furthermore, secure attachment and synchrony throughout the development of mother-infant bond is an important element for life-long psychological resilience. In fact, this relationship is not always optimal and can be influenced by stressors, such as premature childbirth or maternal postpartum depression, which increase the probability of developing psychopathology through reduced synchrony in the relationship.

In any case, it is necessary to consider that risk factors and stressful experiences usually occur multiply at one time, constituting a cumulative effect. Multiple adverse experiences increase difficulties in coping capacities, as theorized by the conception of risk gradients, which refers to "the proportional relationship between risk factors and the probability of manifesting adaptation problems" (Inguglia & Lo Coco, 2013, p.20). Dimensional approaches conform to this aspect by considering the co-occurrence of risks and by analysing different dimensions of adversity and their associations. This kind of analysis considers risk indices and stressful life experiences scores, which can be differentiated according to frequency, duration, intensity, and severity. On the other hand, other approaches simply consider the sum of difficulties, with no regard to the peculiar entity of every adversity and its following impact.

Referring to the qualification of stressors, the *Diagnostic and Statistical Manual of Mental Disorders* (DSM) (American Psychiatric Association, 1987, p.11) identifies six levels of severity of psychological stressors for adults and children. These levels correspond to situations ranked according to changes implied and the individual's possibilities to control and desire certain circumstances. The identified indicators are ordered from a lower to a higher level of stressor severity: none, mild, moderate, severe, extreme and catastrophic. Each level can describe two categories of experience, which are differentiated according to their durance and refer to acute events or enduring circumstances, respectively reflecting minimal impact resilience and emergent resilience. The DSM gives examples of every case for both children and adults; among the examples of child's stressors are described situations like change of school (acute event of mild level), recurrent abuse (enduring circumstances of extreme level) or birth of sibling (acute event of moderate level). In addition, harshness and unpredictability are two other variables that can describe difficulties faced by children and adults, affecting their development in case of severe circumstances. Unpredictability refers to experiences which differ from what is expected, resulting in an increase of harshness with the impossibility of preparing for the adverse event.

Thus, it is essential to consider also the attitude of the person in the face of adversity, linking to risk perception and risk propensity. These attitudes are traits defined according to the individual, whose choices are basically guided by the pursuit of survival and reproduction, as in ecological resilience. Consequently, a person can be characterized by risk-seeking or risk-averse style, where the first may be more efficient in face of unpredictability of future experiences. This predisposition to take risks can vary quantitatively based on the domain of risk, so that risk-seeking behaviour does not correspond to the same level for every domain. Domains of risk constitute five variables that differently shape the style of the individual towards risks and they correspond to: "financial risk-taking, health/safety risk-taking, ethical risk-taking, recreational risk-taking, and social risk-taking" (Wang et al., 2008, p.78). Other variables are represented by seven independent life-history traits, which are: "sex, age, birth order, number of siblings, parental status, reproductive goal, and subjective life expectancy" (Wang et al., 2008, p.78). Because of these variables, the individual tends to adjust their behaviour referring strategically to the situation they are in, as well as the goals and deadlines they set for their life. Wang et al. highlight the role of sex, subjective life expectancy and reproductive goal as main predictors of risk-taking behaviour, with more significant effects on domains of risk. Age, reproductive goal and life expectancy constitute temporal references that shape perception and predilection for risks.

Finally, difficulties can be experienced collectively by communities and groups of people, not just individually, and can have both internal and external origins. Considering the collective dimension, adversity can be referred to as disaster, meaning "a potentially traumatic event that is collectively experienced, has an acute onset, and is time delimited; disasters may be attributed to natural, technological, or human causes" (McFarlane & Norris, in Norris et al., 2008, p.128). The resulting circumstances after the disaster depend on the needs of the community and its capacity to satisfy them, being aware that collectively experienced disturbances cannot be faced by an individual but require collective action.

Other risk factors for communities are connected to diffused criminality and violence or socio-cultural aspects, such as low educational levels. Then, there are also political, economic and geographical aspects, such as geographical isolation.

### 2.1.1 Stress

The term "stress" is connected to effort, tension and pressure, and is characterized by persistent or growing threats. This conception started to appear with the works of Selye, a medical researcher who began to study stress in 1936. In particular, he viewed stress as a global and integrated response, which includes various physiological functions. In this sense, stress involves adaptation of the organism, who defends himself responding generically to any request of the environment. Selye hypothesized a process that describes stress, which is composed of alarm, resistance and exhaustion, and is activated by stressors (Bonino, 2002, p.732).

Stressors indicate environmental factors that interfere with the normal functioning of organisms. Learning and internal representation can constitute a filter for external stimuli, leading to emotional activation of stress if the menace is perceived as concrete. Stress emerges when there is a gap between the environment and the individual, so that they perceive demands as exceeding their resources. Thus, "stress lies not in the environmental input, but the person's appraisal of the relationship between that input and the person's resources to cope with the demands posed" (Luthar & Zigler, 2014, p.4). Behavioural manifestations are somatic and psychic, turning into anxiety in case of chronic or acute stress. In normal circumstances, the reaction caused by stress is functional to increasing the readiness and adaptation of the organism to face external or internal changes, stimulating autonomic nervous system, immune system, endocrine system and corticosteroid hormones. Stress response has always been functional for our survival, preparing the person to act according to the principle "fight-or-flight". On the other hand, acute or chronic stress overstimulates psychophysical and emotional activation, reducing immune defences and increasing psychosomatic risk. The organism can be damaged by exaggerated physiological responses or by persistent stressors that the individual has not been able to manage. Consequently, people need to find ways to regenerate themselves, in order to ease stress and enhance their well-being and health. More specifically, actions aimed at enhancing well-being can be analysed according to the dimensions underlined in its definition as "well-being is 3-dimensional: it takes account of material well-being, subjective well-being and relational well-being and their dynamic and evolving interaction" (Sumner, 2010, in Brown & Westaway, 2011, p.331).

As a result, there can be motivating outcomes or limiting outcomes according to the type of stress involved. Children can be pressured by stressors, learning to compromise, auto-control and find solutions. However, acute stressors can be very harsh for children, because they have not yet developed adequate coping strategies. They still have to experience various situations and build several instruments before disposing of sufficient resources to face severe stressors. Therefore, socio-psychological resilience is not stable in time but can increase when people are able to cope with adversities.

Moreover, compared to adults, children may develop more severe outcomes even in response to minor daily stresses, such as reproaches or scholastic failures, whose accumulation can compromise adaptation and coping strategies. Therefore, they cannot manage stress, but they still manifest alarm signals through their behaviour. Indeed, they struggle to regulate their emotions and their frustration, resulting in reduced concentration, difficulties in relationships and aggressive or opposing behaviour.

The environment can cause stress through multiple stimuli and excess of information. As a result, individuals react through physiological, psychological and behavioural responses, leading to a spread of attention, which can function involuntarily. In this sense, a natural environment is perceived as more regenerative than urban environment, producing pleasure and relaxation. Human cognitive and sensory systems in general seem to prefer natural environments, given that they have evolved through the interaction with such environments throughout history. Regenerative environments are usually fascinating, stimulating, compatible with individual inclinations and coherent with their aim.

From the point of view of measurement, stress resistance throughout childhood is usually calculated by using the life events method, which considers the stressful life events encountered by individuals. It is based on a scale of items to which the child responds, but from the results it is not possible to consider causality. Different studies have attempted to address this gap, particularly focusing on whether individuals have some control over a certain event. Other ways of measuring stress concern the detection of minor stresses of everyday life, which are more frequent and rapid, or the examination of specific stressful life experiences.

## 2.2 Psychological resilience in the development of the individual

Building psychological resilience is usually an explicit aim for the development of the individual, especially in childhood. For this reason, the term is frequently used in association with positive development, even if it can express different meanings and involves many variables. Therefore, it is important to specify these components, identifying the possible ways of understanding psychological resilience.

According to Masten et al. (2009, p.25) "resilience in children arises from ordinary processes" among social systems, describing commonplace human adaptive systems that involve psychology, biology and social relationships of children. Thus, psychological resilience does not emerge from special individual qualities and is consistently linked to the development of the child. Someone's resilience is not determined only at birth but is increased over time. In this sense, the basis of psychological resilience can be found in the initial relationship between the child and the mother, where the brain of the infant is shaped by external regulation and caregiving.

Neurobiology affiliation supports psychological resilience and is formed by oxytocin system, affiliative brain and biobehavioural synchrony, which are related to experiences of attachment in early life. The oxytocin system deals with the mediation of the response to environmental threats, in order to enhance life and its basic processes, which applies to all mammals. This is also fundamental for sociality, where sensitivity to recurring elements in the environment leads to attachment, as in interaction with the mother. Furthermore, oxytocin stimulates a sense of security and desire for social interaction and also supports the immune system. Then, the affiliative brain "charts the network of inter-connected structures that enable humans to form and maintain close relationships" (Feldman, 2020, p.134) or affiliations, which can go beyond human relationships and involve empathy, simulation, mentalization and emotion regulation. Finally, biobehavioural synchrony concerns "the coordination of biological and behavioural signals between social partners during moments of social contact" (Feldman, 2020, p.135). This mechanism is at the basis of empathy and especially describes the external brain regulation that occurs between caregiver and infant, after being originated in the uterus, through a biological interaction that becomes relational. In this interaction it is important to experiment with a balanced and coregulated cycle of matching and mismatching, which allows children to learn how to tolerate rupture, by constantly finding ways to repair the situation. This way of experiencing synchrony and interaction enhances psychological resilience and supports the development of predictions, which compose another feature of synchrony.

Recalling the fundamental nature of the mother-infant relationship, different stressors can occur producing negative effects on their interaction, resulting in long-term outcomes. That said, the child can later progress his functioning socially, by regaining synchrony from friendships with peers. Indeed, later, biobehavioural synchrony is expressed in mutual care and intimate relationships with other people, enlarging the perspective from parental interaction. In this sense, "resilience components function differently at various stages and […] development should become a focus in the conceptualization and research of resilience" (Feldman, 2020, p.142).

Coordinated behaviours are related to psychological synchrony and constitute the base of resilience, with responsibility for processes like emotion and stress regulation, which maintain homeostasis. Biobehavioural synchrony is connected to the building of the "self", which is both based on the actual and potential state of the person.

Based on these elements of affiliative neuroscience, three aspects can be identified for a resilient individual in a social psychological dimension:

- Plasticity, involving flexibility and adaptation. Plasticity comprises resilience as integrative and regulatory or as time-based. Regulation constitutes the basis for development and functioning of the whole, by a flexible integration of the components. On the other hand, time-based resilience develops towards complexity, implying timely processes that start from biological level and evolve to mental level.
- Sociality, a variable aspect which advantages people through coordinated and collaborated action among groups. Sociality firstly extends from the mother-infant bond to other members of the family and then progressively enlarge according to affiliative behaviour.
- Meaning attributed to adversity, trauma and difficulties. Meaning can be referred to spirituality, which enhances consolation and support, or personal actions. Belief has been studied as an important means to build a personal significance to negative events.

These aspects emerge differently according to time and context. Resilience "is thus contextual and emphasizes the role that person and environment have on healthy adaptation" (Bonanno & Diminich, 2013, p.386). This consideration amplifies the perspective on resilience from individuals to multiple systems and contexts, towards a holistic perspective. Socio-psychological resilience corresponds to multiple characteristics that are usually associated to adaptation and emerge from the relationships between individuals and between individuals and their context. Thus, an individual's resilience cannot be entirely attributed to personal responsibility and should be described as pathways of convergence between internal and external factors.

### 2.2.1 Positive key determinants

In psychological studies, the analysis of vulnerability and recovery capacity, corresponding to one way of declining resilience, considers normal and atypical development related to stressors. The main object of study concerns the characteristics that make a child resilient. In other words, what elements make a difference in positive or negative individual outcomes after adversities, referring to positive adaptation, as internal well-being, positive functioning of context, or both.

Adaptation is enhanced by assets, protective factors (for cases of higher risks), social capital, material capital, promotive factors or resources belonging to humans and the managing of these resources. Furthermore, resources such as critical thinking enhance adaptation and can be analysed in terms of robustness, redundancy, and rapidity of mobilization. Consequently, improved qualification and quantification of resources strengthen socio-psychological resilience processes, in which resources are mobilized, but which at the same time deteriorate through their use. For example, the cumulative utilization of coping strategies can produce excessive activation or fatigue, resulting in the reduction of attention and can also have effects on hunger and sleep. However, such resource loss is then reintegrated by the gain of other resources, rebalancing the gap.

Successively, protectors, promoters and predictors are widely studied because of their implications in possible interventions to enhance better outcomes. Protective factors and promoters emerged from processes of biological and cultural evolution in order to attenuate the effects of adversities in childhood, with probable adaptive outcomes especially in case of (Bonino, 2002, p.786):

- Positive relationship with an adult giving stable parental care. Furthermore, the role of familial factors, such as caring and supporting parents constitutes an important protector for the development of children.
- Better cognitive capacities, which are linked to learning and problem solving. In particular, they develop cognitive control processes, which include three important skills for learning and adapting: working memory, cognitive flexibility and inhibitory control.
- Friendly and attractive temperament to get more emotional support.
- Secure context where the individual can experience capability and personal efficiency.

As a result, socio-psychological resilience emerges from protective processes that may refer to both internal or external resources across different conditions, rather than being an isolated and innate characteristic. Moreover, "there may be basic protections for human development that promote competence in general and have protective effects in the context of adversity" (Masten, 2014, p.87), connecting experiences and general development.

Considering the possible resulting pathways after the experience of difficulties, protective factors can benefit everyone, without distinctions based on individual diversity in face of risks, because of the contrasting effects on the maladaptive outcome. At the same time, harsh adversities that cross individual tolerance levels and undermine, harm or damage key promotive or protective influences may carry the greatest dangers for maladaptive outcomes in development. Children can involve competent behaviour or emotional health, as distinct outcomes and consequences of experiencing stressful conditions. Therefore, reactions of resilient children are thought-oriented, describing an internalized process of depression and anxiety, which configures higher development and maturity. On the contrary, action-oriented or externalizing symptoms are typically less controlled, often evolving into aggressive behaviour.

From the point of view of predicting pathways, Bonanno and Diminich (2013) analysed a set of predictors more likely to define minimal-impact resilience, including demographic variation, proximal or distal exposure, personality, socio-economic resources, positive emotions, past and current stress, flexibility, coping and appraisal. Particularly, flexibility means the possibility to use different behaviours and strategies, changing according to time and context. This possibility is connected to coping since it refers to the aim of adaptation, through a flexible use of strategies that are better suited to the characteristics of stressful situations. If coping strategies are efficiently managed according to the request of the situation, it is possible to obtain optimal reconfiguration of an individual's well-being.

Coping strategies can be focused on the problem that caused stress or can refer to emotions, regulating the internal response to stressors. Problem-focused coping is better suited for situations that can change, while emotion-focused coping is more likely to have positive outcomes for irreversible situations. These strategies can be combined, starting the process of coping trough the elaboration of the difficulty, which enables its acceptance and handling. However, this happens only in adulthood, because children do not have adequate mechanism for coping and processing.

"Reducing risk, building strengths or assets and mobilizing adaptive systems that protect and restore positive human development" (Masten et al., 2009, p.1) are three important strategies for fostering socio-psychological resilience, involved in a comprehensive intervention, composed by strategies with different objectives. Risk-focused strategies aim to reduce exposition to risks, for example reducing stress in school contexts. Then, asset-focused strategies are connected to increasing the availability of resources that can have direct impact on children, such as programmes in recreation centres, or indirect impact, such as training for teachers on the subject. Finally, process-focused strategies mobilize protective systems, like in the case of programs designed to build self-efficacy, which foster intrinsic motivation and increase confidence in acting and adapting.

Even emotions can be related to flexibility, by increasing or reducing their expression according to the demand of the situation. In this sense, psychological resilience has been defined as "the ability to bounce back from negative events by using positive emotions to cope" (Tugade et al., 2005, p.1), enhancing "flexibility in response to changing situational demands" (p.5). Positive emotions are associated with psychological health, because through frequent experience of positive emotions, individual resources increase, as well as the possibilities to adapt and cope with stresses. Psychological and physiological responses are connected. More resilient individuals have faster cardiovascular recovery from stressors, a process in which even positive emotions play a role. Thus, psychological constructs can enhance or disturb physical health.

Resilient people face adversities by experiencing positive emotions even in difficult situations, because they understand the favourable outcomes of this practice. Furthermore, resilient people tend to be more precise in their representation of positive emotional experiences, which refer, for example, to the use of humour, creative exploration and optimistic thinking. This tendency is referred to as "positive emotional granularity" and can be analysed determining individual differences. Individuals with high granularity better define the emotion, making more distinctions between nuances of feelings than individuals with low granularity, who perceive emotions as general feelings. High granularity people perceive themselves as more concentrated on their actions and more scrupulous about the consequences. Indeed, they process information about the situation and then they evaluate more options before choosing coping strategies. In general, the careful analysis implied enhances efficient action, building a repertoire of responses that can be differently stimulated and activated. This occurs especially in low-stress contexts, in which there is no urge to respond, so that individuals can be more reflexive.

In addition, positive emotions are linked to broad-minded coping, which means openness to various possibilities to deal with problems, cultivating self-awareness and confidence. Positive emotions and broad-minded progressively increase each other, in a cycle of continuous mutual influence. Consequently, resilience produces short-term and long-term benefits on health, including greater growth and experience of positive emotions after the crisis.

Furthermore, considering personality, three main qualities emerge in a resilient person, as follows:

- Commitment, which implies active involvement in situations and the tendency to face problems.

- Challenge, which refers to conception of troubles as stimulating and motivating, with willingness to make changes.
- Control, which stands for the belief of being able to influence circumstances and events, legitimating agency to ameliorate personal situation. Without perceiving control or influence, individuals can develop learned helplessness, extending inability to create positive outcomes to every situation.

Moreover, focusing on experiences of the individual, counter-adverse childhood experiences (counter-ACEs), like adverse childhood experiences (ACEs), have effects on future adult life, via positive or negative long-term outcomes for mental health. "Connection between ACEs and negative health outcomes could be explained by physiological responses to stress and the tendency to adopt risky behaviours in order to cope with stress" (Crandall et al., 2019, p.2). On the other hand, counter-ACEs stand for positive experiences of the child, for example social interaction, that increase responsibility and productivity of the future adult. These positive experiences help the children build ability to cope with disruptions later in their life, protecting and improving life. Consequently, the importance of opportunities and choices throughout the child's development emerges.

Recalling the three resilience models identified by Garmezy, positive factors can be explained following each model. For example, positive factors can be compensatory by directly eliminating the effect of risks, independently of their characteristics. The effect of positive factors can also be protective, with an increased level of counter-ACEs lowering the effect of risks for adult health. Then, the third possible conceptualization of positive factors is related to challenge, where moderate risks increase adult health with the help of counter-ACEs, but if the ACEs are too great or numerous, positive outcomes are significantly reduced.

Finally, even the experience of risks and stressors can be considered a positive indicator, by implementing some predictor previously explained. Indeed, experiencing difficulties in unpredictable environments improves flexibility and problem solving, by training abilities to cope with troubles. In this way, experience builds neurobiological plasticity and is fundamental during developmental periods, when children need to have certain experiences, dealing with horizontal stressors. Consequently, it is better to experiment with exposure to challenges, crises and risks, especially in controlled contexts, rather than avoiding difficulties.

Furthermore, experiencing risks and adversities nourish persistence, one of the fundamental characteristics of resilience in the ecological perspective, which has distinguished resilience from stability. However, in psychological and social dimension, responding acquires more importance than persisting, enabling coping capacities to face also the unpredicted, since, recalling the Heraclitean notion, "everything changes, nothing remains still" (Keck & Sakdapolrak, 2013, p.9). In fact, social and psychological resilience are based on learning from changes, where uncertainty and surprise are essential.

## 2.3 Resilience in communities and social systems

Communities are social networks composed of interactions between individuals, that usually happen within a defined territory. The analysis of resilience in communities and social systems refers to its sociological meaning as "the ability of communities to withstand external shocks to their social infrastructure" (Bruneau in Norris et al., 2008, p.129). This definition refers to the maintenance of the internal structure despite struggles deriving from influences coming from the outside. After the experience of adversity, resilience's community process begins and develops according to the capacity to absorb the difficulty, recover and creatively adapt. These dimensions refer to the moment following the disruption, but prior community preparedness and prevention are equally important. Indeed, the response also considers possible vulnerabilities, becoming aware of what could go wrong and preparing for it.

In other words, community resilience can be described as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change" (Adger, 2000, p.347). Here, communities are characterized by built, natural, social and economic components, where each one influences the others through a complex interaction, basing the overall resilience on "a set of networked adaptive capacities" (Norris et al., 2008, p.135). In fact, a fundamental characteristic of resilience is the transformability of the community or the individual, implying a change that involves its components and the interaction between them.

Resilience and adaptation refer both to internal and external spheres, since "human individuals are living organisms that must maintain coherence and organization as a unit and also function as part of larger systems, such as families and communities" (Masten et al., 2009, p.7). Both individual and collective action toward a communal objective define a resilient community, focusing on all the strengths combined to enhance self-organizing and agency of the group and the member, as shown in Figure 7.

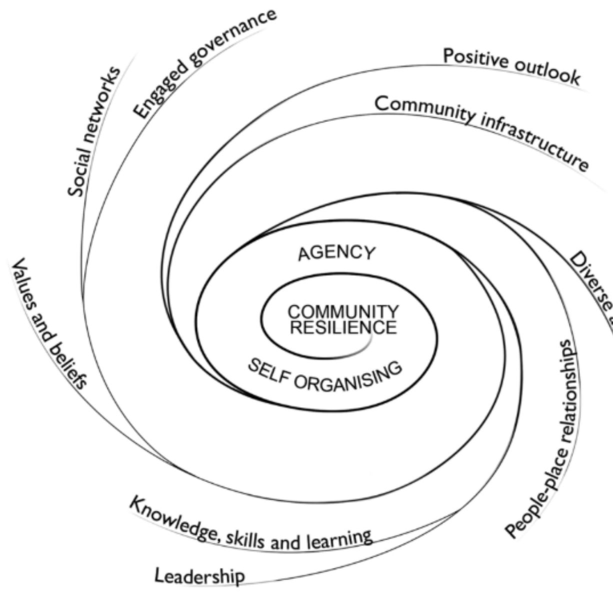


**Figure 7. Representation of community resilience and the strengths or characteristics that sustain it (Berkes & Ross, 2013, p.14).**

In this sense, resilience arises from agency, referring to what the individual and the community can do in face of challenges, on the basis of dynamic processes. The exercise of agency can activate adaptive capacity, conceived as the dynamic learning ability that influences resilience.

Recalling the internal and external spheres, together with broader dimensions, from an ecological perspective community resilience also considers the sphere external to the community itself, because a community is influenced by other communities and social or political entities. In line with the ecological systems model of Bronfenbrenner (1979), children foster their resilience through direct exposure to both risks and protective experiences within microsystems, involving the relationships established with the immediate setting. Then, the interactions in mesosystems extend to major settings, like school, peers and family, which play an important role in the optimal development of the child. The following wider level corresponds to the exosystem and is represented by community and local institutions, which influence indirectly the individual and the family through the provision of services and resources. Finally, government policies and cultural norms relate to the macrosystem, which compose the largest level, influencing and supporting all the previous ones. As a result, all these levels together influence the individual, since every sphere "contains" lower-level systems and connects with them. By enlarging the perspective, the systems grow their dimensions through multiple interconnections that progressively include more actors and increase indirect influences.

This model highlights and reveals all possible interconnections and interactions, so that it is possible to project a holistic intervention to have better outcomes, as presented in Figure 8.


**Figure 8. A HOPE framework based on Bronfenbrenner human ecological model, including possible services that help prevent child abuse, by ensuring better long-lasting outcomes (Sege & Browne, 2017, p.83).**

Health Outcomes from Positive Experiences (HOPE) is a framework that promotes the importance of positive experiences to lower ACEs effects. In this sense, health is enhanced enabling "children to (a) develop and realize their potential, (b) satisfy their needs, and (c) develop the capacities that allow them to interact successfully with their biological, physical, and social environments" (Sege & Browne, 2017, p.80). This holistic framework "includes developing skills in four areas: supportive relationships, safe and stable environments, social and emotional skills, and positive social interactions and connections" (Crandall et al., 2019, p.8). These skills and the related domains concern development of the individual from a physical, cognitive, social and emotional point of view, within a broader perspective on social systems and interactions.

Referring to the broadest level, which encompasses the cultural component, collective narrations and rituals are fundamental promoters for socio-psychological resilience, shaping how community perceives different issues and defines well-being. Culture influences the perception of difficulties, so that the activation of the resilience process is socially constructed based on what is defined as a trouble to face. Then, cultural influence also shapes expectations about proper ways of coping with difficulties and establishes protective factors. This can also be observed among children's education, highlighting the way adults prepare them to face disruptions. For example, adults can create less predictable environments, in order to encourage children's responsibility, while even expectations about developmental tasks and accomplishments vary across culture.

In addition, the characteristics of relationships and interactions within social networks vary depending on culture. On this regard, three main aspects have been identified, which decline differently according to the culture of the community (Prati & Pietrantoni, 2009, p.15):

1. Familismo, which refers to the importance attributed to the family.
2. Respeto, which refers to the importance attributed to elder members of the family.
3. Personalismo, which refers to the value attributed to relationships.

These characteristics shape the meaning of building relationships with others across different communities, highlighting the importance of social connectedness. On the other hand, experiences of rejection stimulate individual's sensibility to the perceived rejection, so that this feeling becomes prevalent and widespread in social interactions. Therefore, through perceived rejection, the person builds insecure models of their relationships within society, developing negative misinterpretation and hostile behaviour. In other words, they amplifiy the perception of rejection within their relationships, reinforcing loneliness through inappropriate responses driven by misinterpretations.

### 2.3.1 Resources for community

Resilience of the community depends on the "existence, development and engagement of community resources by community members" (Magis, 2010, in Berkes & Ross, 2013, p.6). Sets of resources for community resilience correspond to networked adaptive capacities and include economic development, social capital, information and communication, and community competence. Analysing this set of adaptive capacities, economic development concerns, for example, the quantity and variety of available economic resources. In fact, poverty increases risky effects and makes it more difficult to distribute support according to the needs. Means of communication and information dissemination are efficient if they can accurately transmit correct information, responding adequately to the trust of people. Furthermore, narration of adverse events within communities or groups enhances resilience through the possibility of elaborating a shared meaning and a feeling of connectedness. Finding explanations and meanings for adversities but also talking about difficulties facilitate individual ability to face unfavourable circumstances. The group helps with this individual need, through sharing and social support. However, shared intense meaning within the group can lead to rigidity, increasing sociality and resilience just for in-group, while producing the opposite effect for out-group.

Community competence refers to collective action to creatively and critically solve problems via collaboration. Human action is oriented towards transforming physical and social environments in order to ameliorate the capacity to adapt and respond to adversities. The key for facing disasters or adversities in communities corresponds to the ability to variate response and increase flexibility, towards a behaviour of adaptation to new information.

Social capital was identified by Hanifan in 1916 as "mutual sympathy and social intercourse among a group of individuals and families who make up a social unit" (Aldrich & Meyer, 2014, p.3). In this sense, interactive links and networks built through relationships with others constitute inputs for individual resources and social support. Furthermore, social support is responsible for instrumental support, implying financial sustainment and daily help, informative support and emotional support, through empathy and encouragements.

Social support can be distinguished in terms of "received" and "perceived", where both vary according to the source or type of help. Positive outcomes emerge if receiving and perceiving support are reciprocal, which means they are in balance. Community resilience is enhanced by cooperation aftershocks, particularly thanks to informal connections, for example, those created among neighbours. Resilient individuals cultivate the experience of positive emotions for themselves, but they also support the same positive experiences of other close people. As a result, a supportive social network is created, in which positivity increases, enhancing favourable outcomes from adversity. Consequently, crises and adversities have a positive effect on community, by increasing solidarity between individuals. However, networks can have different effects, because they can also be exclusionary if the boundaries are too rigid, leading to excessive insulation.

Moreover, support systems are identified as protective factors for the individual, who lives in a network of relationships and interactions that can be familial, formal or informal. Social environments such as family, school or community context, promote socio-psychological resilience across development by providing opportunities for participation, fostering a sense of belonging, maintaining high expectations for children and nurturing supportive and caring relationships.

In fact, motivational and powerful adaptation systems create opportunities for individuals to experience success, learning through pleasure and enhancing resilience. In this sense, systems such as schools and families ought to provide opportunities for the development of children's talents, feeding self-confidence, self-efficiency and self-regulation of attention, emotion, impulses and behaviour. For example, from the research by Wilks (2008) on academic stress among working students emerges that supporting family and friends moderate stress by increasing socio-psychological resilience. Moderating effects are especially enhanced by friends for academic students rather than family, because they are increasing their independence from family. Investing in human capital by "promoting healthy development and competence is as important, if not more important, than preventing problems, and will serve the same end" (Masten et al., 2009, p.23).

Social support implies the "transaction between the person and the environment" (Tusaie & Dyer, 2004, p.4), requiring action and reciprocity from the individual, because social support has to be built together. The socio-psychological resilience process engages resources that enable the individual to cope with difficulties, but these resources can be provided with the help of individual's social ecology. The needs of the person are satisfied by negotiation with the others, so that social constructions, culture and norms have an important impact on the possibility of the individual experiencing troubles to be resilient. In this sense, resilient outcomes are not connected only to the responsibility of the individual, because personal motivation acts together with social networks facilitating or limiting access to resources. Given these considerations, social organization is responsible for the variation of people behaviour, for example higher cohesion and equity increase the availability of resources and better distribution of them, enhancing recovery and growth. In terms of social capital, other significant components are sense of community, place attachment, participation of citizens and leadership.

Another important feature for community resilience is social memory, which is composed of communal and individual memory. Von Bertalanffy stated that every system has a memory that relates it to past events and shapes its pathways (Von Bertalanffy, 1968, in Wilson, 2015, p.234). Although there is a difference, because natural systems cannot anticipate or predict, unlike human systems. Community learning, tradition and historical stakeholder networks are the main features defining social memory, involving "rites and local "policies" often passed on informally and orally" (Wilson, 2015, p.253). This knowledge can be efficiently transmitted across generations, especially if its processes, means and encoding are adequate to help the message reach future generations without misrepresenting its meaning. The following generation partially learns adaptive capacity from the previous one, implementing the inherited knowledge while experiencing similar difficulties. Consequently, social learning can be qualified as incremental, episodic or transformational, and only the latter nourishes adaptive capacity, because it allows individuals to select what to retain or challenge with respect to inherited knowledge. Therefore, adaptive capacity is shaped by proactive learning and learning after mistakes, since there are different possible pathways concerning disturbances and people learn how to build and choose pathways in better ways, improving progressively, since "competence begets competence" (Masten, 2014, p.86).

On the other hand, social memory can also lead to path dependency if choices are made considering only the learnt possibilities conserved through social memory. Following this consideration, social memory results in limiting the opportunities for alternative choices, so that the community becomes more vulnerable and less flexible, at the risk of disappearing. In addition, social learning is enhanced by strong sense of belonging to the place, connecting to the transmission of traditions. Considering tradition, social learning is modelled according to conscious or subconscious encoded sets of practices and behaviours linked to generational heritage. Even communal effort fosters social learning, when all members of the community are involved in finding a solution after the experience of a collective issue, uniting their resources.

### 2.3.2 The role of diversity

Diversity is characterized by a combination of three aspects that emerge in every field, where "each is necessary but insufficient property" (Stirling, 2007, p.709), because each of them constitutes the other two. Thus, diversity declines according to:

- Variety, which stands for the number of categories for system elements, following a distinction based on the type of elements.
- Balance, which refers to the number of members for each category.
- Disparity, which represents "the manner and degree in which the elements may be distinguished".

This latter aspect is considered the most significant, but it can be understood only in reference to the other two.

The community arises from the diversity and plurality of individuals and their interactions, where their simple sum is not sufficient to explain the complexity of reality, because of the differences and variables. This also applies to socio-psychological resilience, since people are resilient in different ways between them, and resilience of the group is not equal to the sum of individual's resilience. Thus, exposure to adversities and risks defines what can occur to any individual, while experience highlights personal perception, producing different possible reactions according to individual characteristics, their recent story and their broader life circumstances. Consequently, it is necessary to expand the perspective from exposure to experience, in order to understand the development and the meaning of personal resilience.

Individual differences emerge when people face adversities and stresses, by changing response according to the type of difficulty or outcome. Indeed, someone can be resilient to certain adverse circumstances but not to others because everyone acts and reacts uniquely. Indeed, individual differences are related to the peculiar characteristic of each person, which cannot be reduced to psychological traits, because other aspects interfere, such as susceptibility or physiological responses. In the case of diagnosis for pathological outcomes, personal perception tends to be less considered, focusing on the categorization of risks, as described by the relative severity of psychosocial stressors.

Finally, personal resilient outcomes emerge from the interaction between individual characteristics and the environment, but also from the interaction between risk and protective factors, whose balance is always dynamic. In particular, "the way children cope with stressors vary across domain, development, and context" (Freitas & Downey, 1998, p.263). This applies to all ages, adding that everyone changes their way of being resilient and responding to stress over time.

In summary, according to cognitive-affective personality system (CAPS) model, the main aspects characterizing the process of socio-psychological resilience typical of each individual are: "(a) context […], (b) psychological mediating units […], (c) a focus on how psychological mediators are organized in relation to one another and to relevant features of the context" (Freitas and Downey, 1998, p.268). In this sense personality guides similar behaviours following similar psychological contextual circumstances, producing a certain degree predictability. Of particular importance is the mutual interaction between individual mediating units, like competencies, expectancies or values, and context, with each influencing the other.

As a consequence, competency could bring protection or risk according to the situation, so that it is not possible to generalize its entity. Then, competencies interact with the other mediators and context, producing the individual way of responding and deciding, consequently expressing an adaptive or maladaptive outcome. From a collective point of view, group actions are differentiated according to cognitive diversity, which corresponds to variety of experiences, modes of inquiry and preferences. The first two enhance cooperation and learning toward problem solving. These aspects involve general intelligence and social intelligence, whose higher levels increase functional diversity and whose interaction leads to sustainable outcomes. General intelligence describes knowledge about the environment, while social intelligence describes knowledge about communication with other individuals.

Thus, just as with ecological resilience, psychological resilience is enhanced by diversity. Both functional redundancy and response diversity between actors of the community improve coping capacity. Redundancy is given by more ways to solve a problem and wider social networks or range of resources, expanding the possibilities of solution because the elements can be substituted. In this sense, redundancy should characterize critical components, so that the functionality continues even if a source is damaged.

# Chapter 3. The dimensions of social-ecological resilience

Social-Ecological Systems (SES) thinking emerged in the late twentieth century and has developed a set of concepts to understand and model the interlinked dynamics of social and environmental change (Berkes & Folke, 1998). The social and ecological dimensions of resilience bring together social systems and ecosystems as interdependent and coevolving. It is not possible to clearly understand the social and ecological spheres as isolated from one another, and the interrelationship between them cannot be reduced to the simple sum of these systems. Scientific enquiry in this field has evolved to embrace holistic and overall perspectives, considering the broader sense of component parts, as well as interactions and influences that characterize them. In this way, the analysis conducted can better reflect the complexity of reality, enlarging the approach to encompass various disciplines, as suggested by Odum (1977), who asserted that the natural, social and political sciences should be integrated, in order to obtain new understandings related to thought and action through an interdisciplinary perspective.

In this sense, resilience can be seen as a boundary object, because it enables inter- and indeed transdisciplinary connections through communication between different dominions via the constitution of a shared lexis. The openness of the boundary object bridges various perspectives, thereby enhancing dialoguing and expanding meanings. At the same time, some scientists have warned about a risk of a lack of clarity at certain levels. This can occur logically, because "any concept that encompasses very much, i.e., wide extension, must lose specific meaning, i.e., clear intension" (Brand & Jax, 2007, p.9).

As we have already seen in the ecological and socio-psychological fields, as a concept resilience can have a broader or a more precise meaning, and we can distinguish between general and specific resilience, depending on the elements considered in the analysis conducted. Specific resilience refers to the definition of *what* is resilient and *to what* it is resilient, identifying a specific resilient part of the system, a particular controlling variable and a precise kind of shock. In this way, the scope of analysis is more restricted, whereas in general resilience all parts of the system are considered as resilient to all kinds of shocks (Folke et al., 2010).

Furthermore, given the various domains implied in social-ecological resilience analysis, the meanings of this concept can evolve according to the different objectives of the given social or ecological field. This consideration leads to an even wider and potentially more ambiguous perspective, whereby resilience should be defined as an approach, rather than a concept, referring to a set of ideas about how to interpret complex social-ecological systems. In this sense, "resilience should be thought of as a framework for systematically thinking about the dynamics of SESs" (Anderies et al. 2006, p.3). This representation of resilience would better reflect the nature of social-ecological systems, which are complex adaptive systems characterized by a heterogeneity of ecological and social elements, with multiple agents and components that usually interact unpredictably.

Furthermore, complexity is also reflected in the increased level of connectedness with the Anthropocene, which has produced new interconnections that develop rapidly from a local to a global scale, multiplying challenges. Anthropocene thinking involves the rapid planetary changes caused by human social transformations, such as urbanization and industrialization. Indeed, human activities have massively increased the utilization of available resources and led to "a state change in the Earth system" (Brondizio et al., 2016, p.319).

The conceptualization of the Anthropocene has raised awareness both of the human impact on nature and of the need for human agency to address the multiple current complex problems faced. To achieve this goal, SES thinking aims to enhance collaborative research, serving as a bridge between society and ecology, toward an interactive understanding of sustainability. In this sense, such complex systemic thinking should be promoted, unifying also opposite concepts and separated categories.

As of around the year 2000, there has been a rapid increase in the evolution and adoption of a social-ecological perspective. Previously, studies and the published literature on resilience were focused on separate disciplines, but increasingly have become more holistic, integrating various perspectives. Berkes and Folke (1998) began to use the integrated social-ecological systems perspective in relation to resilience, where the social component stands for human dimensions, while the ecological component refers to the biosphere. In essence, these components are interactive and bring together "(1) agents ranging from microbes to plants to humans, each with a different degree of information-processing capacity; (2) a set of allowable actions related to their physical or behavioural characteristics; and (3) a physical substrate that includes chemicals, light, and water" (Anderies et al., 2006, p.1). In this sense, agents and their environments are included in social-ecological perspective, where emergent properties arise though the dynamic complexity of the systems.

In this respect, interactions are multiple and can occur variably between the components, for example, between agents or between agents and their environment, crossing different levels and resulting in complex non-linearity. In the bidirectional environmental and individual interaction, modularity is a resilient attribute, providing the "right amount" of connectivity between natural places, societies and organizations. Over-connected systems can be subject to the rapid spread of disturbances, like diseases, while under-connected systems respond more slowly to difficulties and are less likely to increase their learning ability. Thus, to highlight the positive outcomes of interaction and connectivity, resilience has been defined as the capacity "of both individuals and their environments to interact in ways that optimize developmental processes" (Ungar, 2013, p.256). Here, the interaction focuses on positive outcomes that can emerge for both components with an improvement in development.

Building on these initial considerations, social-ecological research has evolved in various directions. For example, one of the developments in social-ecological systems analysis refers to the concept of "panarchy", which highlights the multiple spatial and temporal scales related to these systems (Gunderson & Holling, 2002). Panarchy refers to complex systems that are collocated within interconnected scales, where systems are embedded within larger systems belonging to broader scales. As a result, it is not possible to understand a social-ecological system by analysing just one scale. Indeed, panarchy suggests that every scale can have influences on the others, through a nested hierarchical organization of adaptive cycles. Different phases can follow each other in the adaptive cycle, shaping decision-making from conservatism (stability) to change (transformability), since crises make adaptation necessary. This variation leads to a growth stage and then to a renewed phase of conservatism, resulting in path dependency if the decisional context does not adapt to changing circumstances. The decisional context corresponds to broader scales, which define rules, values and knowledge.

Thus, the study of social-ecological systems involves considering them across different dimensions, from local to global scales, including diverse levels of complexity. Social and ecological aspects are dynamic components characterized by interdependence, through complex feedback loops and cascade effects (Cascade Institute, 2026). System thinking is needed to analyse the complexity of the reality that describes these systems, considering interdependencies based on the exchange of changes, causes and consequences within and between them.

Sustainability is another concept closely related to that of resilience, referring both to social and ecological components. Sustainability considers "the maintenance of natural capital in the long-term in order to provide ecosystem services that provide instrumental as well as eudaemonistic values for human society" (Brand & Jax, 2007, p.5). Sustainability involves the use of the environment and its resources in respect of both present and future needs, ensuring that today's actions should not compromise the wellbeing of future generations. Many theories and approaches have been developed concerning the concept and achievement of sustainability, and it is difficult to identify a unifying vision. At the same time, as we will see, it is an essential thread within thinking on social-ecological resilience.

The purpose of the following sections is to examine resilience from different points of view on the interdependence between its ecological and social components, considering how each supports the other. In particular, the role of change will be emphasized, specifying both adaptative and transformative components. The relationship between context and human beings will be analysed, considering the impact of human actions on the environment and human dependence on ecosystem functioning. The initial focus will be on the availability of resources and the resilience attributes of social-ecological context. Subsequently, we will examine the concept and role of human agency and of human responsibility in endeavouring to promote sustainable trajectories and enhance social-ecological resilience.

## 3.1 The role of change in social-ecological resilience

Change is a fundamental element of resilience conceptualization, since "there is no balance of nature, but nonequilibrium or multi-equilibrium conditions, unpredictable systems, subject to cycles of continuous change and renewal" (Berkes & Ross, 2013, p.7). In this sense, changes and unpredictability underlie the complexity that characterizes the reality in which social-ecological resilience operates, both responding to changes and generating changes. Therefore, purely predictive and scientific approaches examining non-linear reality fail in representing it, while approaches based on experimentation, co-creation of transformation and adaptive learning are better suited.

In this respect, the theory of dissipative structures, developed by Prigogine and other collaborators (Gallopìn, 2006, p.299), offers an example of an approach suitable for the dynamicity of complex systems such as social-ecological systems. Following this theory, systems preserve their structural order through openness, self-organization and active exchange with the external environment, remaining far from the equilibrium. This allows the maintenance of stability, since fluctuations are absorbed within the dynamicity of the system as long as they remain below the threshold. When the limit is exceeded, the system deals with instability and entropy, before finding a new structure that confers stability.

The core of resilience thinking reflects the principle of dynamic change, which can have desirable and undesirable outcomes, and usually involves surprise. Focusing on the declination of forms of change, both fast changes and slow changes are involved, but typically human beings tend to respond more readily to rapid changes, because slower ones are less perceptible and associated with a reduced perceived ability to influence them. Moreover, considering the origins of social-ecological systemic changes, they are implied in various situations and are driven by different factors:

- Environmental pressures, which refer to ecological crises.
- Social disparities regarding resource access.
- Technological advancements that propose new solutions for sustainability.
- An increase in public awareness of sustainable options, contributing to form new values.

General resilience refers to adaptability and transformability in relation to unexpected events, involving "diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership and trust" (Carpenter et al., 2012, p.3249). These aspects are connected to rational choices and responses after adversities, even though such situations often generate irrational reactions, especially in severe circumstances.

These characteristics form the basis for principles that enhance resilience in social-ecological systems: "(1) maintain diversity and redundancy; (2) manage connectivity; (3) manage slow variables and feedbacks; (4) foster complex adaptive systems thinking; (5) encourage learning; (6) broaden participation; and (7) promote polycentric governance" (Folke et al., 2016, p.2).

These aspects and principles will be discussed in more detail in the following sections of this chapter, with a focus on examining the possibilities for human activities. At the same time, the principles need to be contextualized according to specific circumstances, considering whether their implementation leads to increased social-ecological resilience or contributes to imbalance and inequality. Additionally, from an intervention and action perspective, it is more difficult to build or plan scenarios for general resilience than for specified resilience.

### 3.1.1 Adaptation

Resilience thinking relates to complex social-ecological systems, where the intersecting concepts of resilience, adaptability and transformability are crucial. The adaptive capacity of social-ecological systems involves the capability to improve system conditions, whether the environmental contingencies change or not. Indeed, a system could adapt even without coping with external changes, with the aim of improving its conditions or extending its adapting to wider environments. However, in the context of resilience, adaptation is usually implied in the process that follows the experience of difficulties and adversities, where the system is able to absorb difficulties and change in order to adapt without modifying its function and identity. Adaptation is required to cope with adverse conditions, involving capacity for response, an attribute of the system that moderates damaging effects and takes advantage of opportunities, towards transformation. Adaptation of social-ecological systems could be detected on the basis of the main characteristics of resilience. Therefore, the changes involved relate to the multiple spatial and temporal scales of panarchy, an initial capability to resist disturbance, precariousness and latitude, i.e., the proximity of the system to a threshold and, consequently, to its difficulty in recovering if the threshold is crossed (Folke, 2006).

In this sense, a social-ecological resilience process is stimulated by the encounter of difficulties, which have different origins and characteristics, and are often faced simultaneously, especially in complex adaptive systems. These perturbations and stresses confronted by systems can emerge internally or externally, because of the disruptions and modifications that can happen through internal or external interactions. Indeed, every system must constantly exchange information, energy and matter with its surrounding environment in order to survive, and through this exchange alterations can emerge. Moreover, a disturbance can be either internal or external according to the point of view of the observer considered (Walker et al., 2004).

Furthermore, adaptation in complex systems involves multiple levels and changes, with the possibility to develop adaptability for one level and specific conditions. Consequently, if conditions vary or if another level is considered, the adaptability could be inadequate. According to spatial, temporal or organizational scales, lack of adaptability could be demonstrated by varying the point of view. For example, when referring to organizational scale, what may be positive for the individual may not lead to common good for the collective whole (Walker et al., 2004, pp.5-6).

Thus, adaptation analysis can be declined according to the perspective adopted, focusing just on one type of issue or level. For example, adaptation can be linked to climate change, considering only the adjustment to this kind of variation.

### 3.1.2 Transformation

Social-ecological resilience encompasses both adaptability and transformability, Where the former involves a system absorbing difficulties and changing as a response, the latter underlies the evolution of the system into a new form, "bouncing forward to a different, more desirable configuration" (Sustainability Directory, 2025, section "Resilience and transformability" of the page "Socio-Ecological System Transformation"). When incremental adaptation is no longer adequate to change and complexity, system responses or decisions taken should follow the path of transformation. From a resilience perspective, a transformed system changes thresholds, outputs and feedback variables as compared to its previous form. Transformation differs from adaptation, since adaptation entails a shift within the same system, which is less impacting than transformation and can be intentional or not. "In the social–ecological systems strand, resilience is the capacity of the system to continually change and adapt and yet remain within critical thresholds" (Berkes & Ross, 2013, p.6), while retaining "essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004 in Folke et al., 2010, p.1). Adaptation involves an adjustment without changing the current trajectory, while transformability crosses thresholds and creates new stable states.

Furthermore, transformability corresponds to the ability of creating "untried beginnings from which to evolve a new way of living when existing ecological, economic, or social structures become untenable" (Walker et al., 2004, p.5). This constitutes the basis of social-ecological resilience and is enhanced by social learning. In this way, knowledge and resources are connected in new synthesis, providing options for action at different levels, so that it is possible to learn by gaining experience. Learning in social-ecological systems can be incremental, episodic and transformational, where the latter focuses on cross-scale effects and novelties. For transformational learning to occur, systems must be open and tolerant of failure, using system memory to determine what to maintain and what to change. In fact, in general learning situations, individuals or systems can benefit from previous experiences to better cope with difficulties, because they are better prepared for them.

Moreover, transformations can be deliberate, with people beginning them, but also forced by external conditions, and this variability depends on the transformability of the social-ecological system. In particular, deliberate change can be applied at different levels and tends to be more effective when initiated at lower scales, from which it can spread to upper levels. On the other hand, forced transformations tend to occur at larger scales and when the transformability rate of the system is high, deliberate transformation may emerge simultaneously, in opposition to these broader forces.

In addition, social-ecological system transformation follows the complexity of the system itself and is characterized by "a continuous, multi-level, and multi-phase process involving both gradual and rapid changes across various scales" (Sustainability Directory, 2025, section "Intermediate" of the page "Socio-Ecological System Transformation"). This means there can be multiple states of existence for a social-ecological system, leading to changes and regime shifts within given thresholds. Otherwise, the structure and behaviour of the system undergo a complete change. As in the concept of panarchy, various scales and levels are connected, spreading the effects of changes, since transformations are never independent, but always have consequent effects across scales. In fact, "(1) social-ecological systems, in the main, have nonlinear dynamics that result in multiple stability domains, and (2) the pattern of their dynamics over time tends to conform to one of the variants of linked adaptive cycles at multiple scales" (Anderies et al., 2006, p.7).

Finally, social-ecological resilience can be explained through a framework encompassing both vulnerability and new perspectives to cope with current global changes. Uniting the dimensions previously analysed "resilience can be defined in its most general sense as a system's capacity to persist in its current state of functioning while facing disturbance and change, to adapt to future challenges, and to transform in ways that enhance its functioning" (Keck & Sakdapolrak, 2013, p.8).

## 3.2 Interconnections between environment and human action

Today, there is basically no place on Earth that is not influenced by human activity and thus all ecosystems can be considered human ecosystems. At the same time, humans must be considered as a part of the ecosystem. Indeed, "humans are intertwined with the biosphere, and the emergence of the Anthropocene now suggests that humans have become a significant force in the dynamics of the Earth system at the planetary level" (Folke et al., 2016, p.1). In fact, almost all ecosystems are heavily shaped by human actions, since human beings interfere with their dynamics, affecting the social-ecological network and resilience through different possible routes:

1. People can link ecosystems by the exchange of information or material.

2. People's actions can create connection or fragmentation between ecosystems.
3. People can generate new ecological networks.

These interferences generate variations in the original features of ecosystems, like climate, water, atmosphere and land surface. Furthermore, "we have altered the capacity of ecosystems to buffer disturbance" (Elmqvist et al., 2003, p.488), undermining the ecological resilience of the biosphere, while it may be essential for the support of natural resources and ecosystems services. In this way, human actions threaten the efficiency of services and functions that are fundamental to human life, so that, through its influence on the environment, humanity obtains negative feedback affecting its (as well as all other living organisms') quality of life.

Human action has a massive negative impact on biodiversity. Since the arrival of human beings on the planet Earth, vast numbers of species have become extinct. From the very beginning, human activity, especially through hunting, had a greater influence than climate change on prehistoric extinctions. Currently, this trend continues and human-driven overexploitation of resources or habitat conversion are the main causes of the decline in species diversity. Invasive species introduced by humans, disease and urban development also contribute to the loss of biodiversity. The impact of climate change is increasing, driven by human activity and contributing to an amplification of species decline. As a result, changes concerning habitat, species richness and climate have consequences on ecosystem functioning and its services.

In the past, Earth system changes were usually caused by external or internal variations that were re-configured within the system, but human activities have introduced impacting planetary-scale consequences. As a result, the anthroposphere component is now exerting an ever-greater influence on the Earth system together with the biosphere and geosphere components, both of which are increasingly conditioned by it. In this sense, the planetary boundaries framework identifies nine key processes which are fundamental to the social-ecological resilience of the system composed by the whole Earth, recognizing the safe limit of the anthroposphere effects for its maintenance. The framework underlies the uncertainty of the processes considering them in an interdependent perspective, where crossing boundaries increases the risk for irreversible environmental changes. What emerges is that seven processes over nine have crossed the boundaries, as represented in Figure 9.

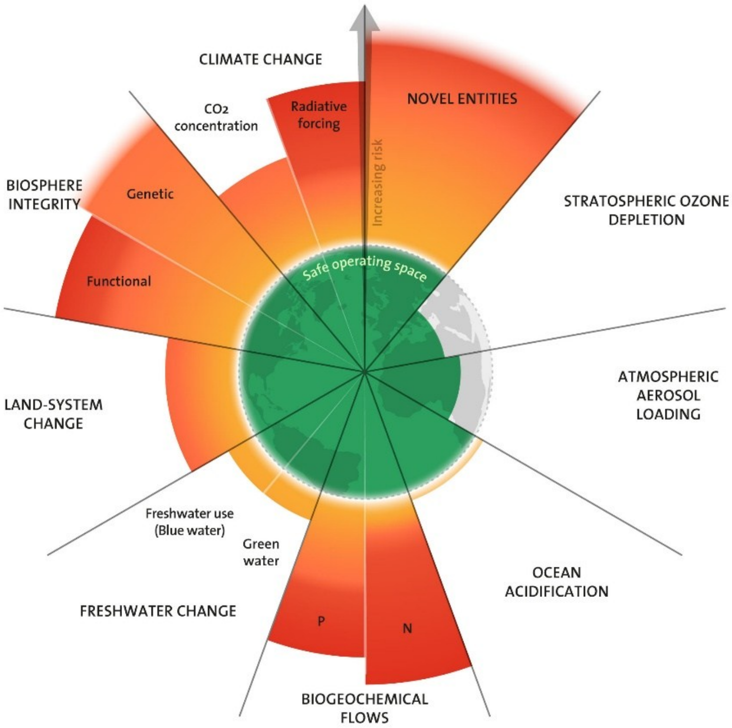


**Figure 9. The 2025 update to the Planetary boundaries (Stockholm Resilience Centre, 2025).**

The figure highlights the severe impact of human action, which has altered the functioning of Earth system, reducing its resilience. Even if there are still some scientific open questions about the exactitude of these findings, human action is confirmed to place "unprecedented pressure on Earth system" (Richardson et al., 2023, p. 11). As a result, human activities will increase future variability and uncertainty, shaping both disturbances and the responses that follow.

### 3.2.1 Human environmental dependency

The expression of individual resilience depends on the proximal and larger contexts, highlighting the importance of developing a holistic framework that includes all these influences. Social-ecological systems operate within the biosphere and depend on it, since ecosystems deliver ecological, or ecosystem, services which are essential for human (and all other) life, providing food production, water purification, and aesthetic enjoyment (Haines-Young & Potschin, 2013). In particular, ecosystem services describe positive outcomes that humans get from ecosystems, and include provisioning, regulating, supporting and cultural services. These services arise from interactions and interconnections between animals, plants, microbes and the physical environment of the ecosystem. In addition, ecosystems are responsible for goods and functions which are essential for human life, concerning regulation, production, habitat and information. In this sense, the environment stimulates psychological growth and well-being through its services and functions, but at the same time is threatened by decline caused by the changes our planet is going through. Following these considerations, resilience can be defined as the capacity of social-ecological systems to adapt and transform in face of changes, especially unpredicted ones, in order to support human well-being.

Social-ecological resilience is also related to the concept of criticality, which refers to situations where environmental degradation prevents life as we know it today from continuing in the same way. Criticality declines according to various degrees and domains, following the same domains identified to define the natural capital. Additionally, criticality is specifically contextualized in time and space, because it varies according to the habits and lifestyle of human beings. Therefore, environmental criticality is related to the physical area and is given for example by the fragility driven by resource utilization in a system.

Criticality is also described in terms of the critical natural capital, a concept which originated in the economic context and was developed by Turner in the 1990s (Brand, 2009, p.608). In particular, the significance of this concept varies according to the main domain in which it is used, but generally it stresses the irreversibility of losing natural capital, because it cannot be substituted by manufactured capital or other forms of natural capital.

Critical natural capital is central to the concept of resilience. Resilience can help identify and decrease criticality, assessing the degree of threat that a specific ecosystem may face. Society establishes the importance of natural capital, which changes throughout human activities, and "the degree of threat ecosystems are exposed to is assessed based on changes in quantity and quality of the remaining natural capital" (Brand, 2009, p.609). In this sense, the empirical estimation of "ecological resilience is inversely related to its degree of threat" (Brand, 2009, p.610). This can lead to an identification of the natural capital that needs to be protected to ensure future life.

Environmental dependency characterizes the conditions that determine human resilience, linked to the need for resilience driven by resource dependence, but also to the attributes of the social-ecological context in which human resilience develops. In line with this, the social-ecological perspective analyses the resilience of institutions, which are responsible for rules and habits that lead the behaviour and life of the community. The resilience of institutions depends on their evolution in time, organizing societal functioning to maintain social capital. In this sense, institutions play a central role in the connection between society and environment, because they shape this relationship through different values and conceptions related to human-nature interactions.

Considering the influence of institutions, resilience can be observed in social systems by analysing economic structure and demographic change (Colantoni et al., 2020). From the economic point of view, stability of economic well-being and economic growth are indicators of social resilience. In addition, a larger range of resources on which societies depend attenuates the unpredictability of their availability, especially given environmental variability. On the other side, from the demographic point of view, migration and population movement can be indicators of stability or instability, depending on the reasons that motivate them. Indeed, seasonal migrations are important for social stability, while migrations lead by external stress imply instability. Additionally, migrations are driven by resource dependency, thus they can be considered an indicator of low resource availability.

Moreover, environmental dependency highlights cultural sensitivity, since resources for resilience are useful if valued culturally (Wardekkar et al., 2022). Indeed, resources should be offered as opportunities, in response to individual needs, freeing their choices. In this sense, a facilitative environment is an influential factor, together with individual agency, and it is not clear which of the two has a greater influence, thereby affecting the possibilities of intervention. Furthermore, any aspect of the environment has a different impact on the individual, depending on the context where they live. Even individual qualities, such as personality and temperament, have various effects according to contextual circumstances, which influence an individual's responses.

As a result, if the environment is protective or facilitative, it has the potential to promote positive growth, even after adverse experiences and despite individual differences. Indeed, a facilitative environment has a greater impact than personal qualities on positive changes in individual functioning. In addition, the protective characterization of the environment is more perceived by individuals with reduced resources at their disposal. Following these considerations, "nurture trumps nature when it comes to predicting resilience" (Ungar, 2013, p.258) and interventions should focus on improving environment rather than changing individuals, since "development is less biologically determined than it is socially facilitated" (Ungar, 2011, p.4). Indeed, adaptive changes are promoted by the availability of resources provided by the environment to the individual.

Returning to Bronfenbrenner (1979), individuals are profoundly connected to the environment and the community that surrounds them. In this sense, the context is essential for understanding healthy development and socio-psychological resilience in youth. For example, a phenomenological variant of ecological systems theory (PVEST) (Spencer et al.,

1997) focuses on cultural and social influence on individuals, relating to the interconnections between systems. The model considers individuals' perceptions and interpretations of social and cultural influences, which are related to personal changes. Indeed, personal interpretation of circumstances is an important factor in building individual resilience. In Bronfenbrenner's model emerges the centrality of immediate settings and social formal or informal contexts, in connection with physical environments. Such an approach promotes the consideration of multiple elements at the same time, identifying the combined impact they all produce together throughout change of circumstances.

In conclusion, human activity and environmental change continuously shape each other in an interrelated manner through a series of multiple complex cause-and-effect relationships.

## 3.3 Agency and possible interventions

The social-ecological approach unites social systems and ecosystems, that share similar resilience processes but are characterized by a fundamental difference:

> While the structural complexity of both ecological and social systems can be conceived of in similar terms, the feedback processes associated with each are incomparable: social systems are unique in that the tendencies toward complexity, and the responses of individual organisms to those levels of complexity, are defined not solely by structural variables, but by agency" (Davidson, 2010, p. 1142).

Agency represents the central distinction between social and ecological systems in their responses to adversity and complexity. In fact, unlike ecosystems, human social systems are non-linear and cannot return to their previous state after disruption, because social learning and social memory produce transformation. As a result, in social resilience, problems and changes are more likely to be seen as opportunities for development, since transformation is the only available possibility. On the other hand, ecological systems can transform but also recuperate their original state.

Considering natural resources availability and ecosystem services problems, adaptive management and resilience concern human adjustment in response to the unpredictability linked to it. In this sense, social learning is enhanced by adaptive management, as well as novelty, which can be created by humans by proposing transformation to deal with uncertainty.

Transformation of social-ecological systems satisfying human expectations about their welfare is composed of different phases comprising preparation, transition and reorganization of resilience according to the new trajectory (Gunderson & Holling, 2002). The process of transformation starts with the identification of issues, thresholds and barriers, in order to consider the potentiality for variations. Thus, problems in initiating the process of transformation emerge in case of persistent barriers such as path dependency, where unsustainable practices continue to be followed because of historically made decisions. Indeed, transformation also depends on new cultural narratives, involving both individual and systemic change.

During transformation it is important to seize opportunities through flexibility in response and face crises, while maintaining cross-level connections. Then, when the new state is attained, it is necessary to foster networks and values that rely on stewardship (Ritter & Sägesser, 2025). In this process of transformation, knowledge, networking and leadership are critical aspects, especially concerning the capacity to create opportunity by promoting diversity of ideas and new propositions.

Agency characterizes human individuals and is linked to their adaptive capacity and learning, since they are never passive in face of environmental disturbances. This is linked to the unique capacity of humans to plan for the future and reflect about the effects caused by their actions. In particular, four aspects are identified for enhancing human adaptive capacity in social ecological systems, as shown in the table of Figure 10.

| |
|---|
| **Learning to live with change and uncertainty** |
| Evoking disturbance |
| Learning from crises |
| Expecting the unexpected |
| **Nurturing diversity for reorganization and renewal** |
| Nurturing ecological memory |
| Sustaining social memory |
| Enhancing social-ecological memory |
| **Combining different types of knowledge for learning** |
| Combining experimental and experiential knowledge |
| Expanding from knowledge of structure to knowledge of function |
| Building process knowledge into institutions |
| Fostering complementarity of different knowledge systems |
| **Creating opportunity for self-organization** |
| Recognizing interplay between diversity and disturbance |
| Dealing with cross-scale dynamics |
| Matching scales of ecosystems and governance |
| Accounting for external drivers |

**Figure 10. Adaptive capacity and resilience in social-ecological systems facing environmental change (Folke et al., 2003, p.355).**

Adaptive capacity depends on the recognition that adaptation is possible and desirable, but also on the utilization of the available resources. Indeed, adaptive capacity does not lie only in individual capacities, as represented in the table of Figure 11.

| **Individual differences** |
|---|
| Cognitive abilities: IQ scores, attentional skills, executive functioning skills |
| Self-perceptions of competence, worth, confidence: self-efficacy, self-esteem |
| Temperament and personality: adaptability, sociability |
| Self-regulation skills: impulse control, affect and arousal regulation |
| Positive outlook on life: hopefulness, belief that life has meaning, faith |
| **Relationships** |
| Parenting quality: warmth, structure and monitoring, expectations |
| Close relationships with competent adults: parents, relatives, mentors |
| Connections to prosocial and rule-abiding peers (among older children) |
| **Community resources and opportunities** |
| Good schools |
| Connections to prosocial organizations (such as clubs or religious groups) |
| Neighborhood quality: public safety, collective supervision, libraries, recreation centers |
| Quality of social services and health care |

**Figure 11. "Attributes of individuals and their contexts associated with resilience" (Masten and Powell, 2003, p.13).**

These attributes recall the protective factors already described in the previous chapter, which, together with the preceding statements, highlight the interrelated nature of social-ecological resilience, whose understanding is embedded in a contextually situated and multi-level framework. All of this results in the consideration of subjective and relational aspects that, alongside with more objective measures, determine responses to environmental changes.

Respecting these considerations, it is possible to identify interventions for adaptive management, even if it would always be hypothetical, since it is not possible to predict system reaction. In particular, management should focus on variables, alternative states and thresholds, rather than maintenance of the optimal state or the control of natural variability. Moreover, considering the possibility for interventions within changes, actions should be particularly promoted for the maintenance of areas with greater chances of persistence and should broaden future possibilities. In fact, it is not possible to predict what will be best suited to future conditions. Therefore, maintaining a wider range of options increases the possibility of meeting needs. In addition, actions should not compromise future generations through present overexploitation. Procedural and distributive justice should be applied across generations. If the initial choice involves more resilient actions, consequent changements are less likely to be required in changing circumstances, since the chosen actions can adjust to them.

Anderies (2006, pp.10-11) proposes a framework that integrates elements of ecology, economy and social sciences. He suggests various possibilities for guiding management and connected actions that enhance the resilience of the social-ecological system:

- To analyse multiplicity of levels, and their cross-scale connections.
- To identify key variables that are fundamental in any change and relate them to thresholds, while recognizing when the state of the system may vary.
- To promote diversity.
- To realize that resilience is costly, requiring to sacrifice short-terms benefits, in order to achieve long-term efficiency and lower future costs.
- To identify opportunities for interventions, considering adaptive capacity, possible effects and appropriate timeliness.
- To amplify common underlying mental models to increase connections.
- To follow adaptive and flexible governance.
- To recognize that transformation is necessary when adaptation is too costly.
- To acknowledge that vulnerabilities always persist and may be transferred to other domains.

These guidelines are intended for the system level and propose ways to organize for increasing social-ecological resilience. In addition, even interventions focused on community resilience could represent a way of achieving the same objective, by investing in coping strategies and recovery outcomes, as suggested in Figure 10 and Figure 11. Social cohesion plays an important role in situations of difficulty, such as natural catastrophes, where bonding, bridging and linking social capital help mobilize the support needed. Consequently, these feelings of trust and sharing enhance recovery and readiness in the face of risk. Hence, social capital implies favourable effects and is nourished by projects or events that involve the community, such as volunteering projects or after school programs. In these situations, people have the opportunity to spend some time together, fostering a sense of connectedness. Positive outcomes linked to social capital are reduced in case of significant losses and severe difficulties for the community.

From a community perspective, place attachment is the first capacity identified as responsible for enhancing resilience of community, since it increases the willingness to protect the place in which the community lives. Then, other capacities are recognized as promoters of resilience, including leadership, community networks and cohesion, knowledge and learning. As regards leadership, it is preferable for it to emerge from the community, considering its needs, rather than being imposed externally. However, it is not possible to identify a universal mechanism to enhance social-ecological resilience, because context and interaction variables always matter. Every resource attributed to environmental, individual or social ecology is helpful only if it is relevant in the specific context.

### 3.3.1 Response diversity in social-ecological actions

Response diversity stands for the heterogeneity of human reactions to difficulties, changes and opportunities, leading to multiple actions, decisions and strategies. The analysis of these variations is connected to the causes and consequences of different reactions among people.

As described in the previous chapters, diversity is an important element for resilience of the social-ecological system. In fact, systems with high response diversity ensure themselves against failure and mistakes, by learning and adapting through an increased tolerance. Therefore, variability in coping with disturbances enhances reorganization of social and ecological components of the system. Multiple choices and decisions in response diversity promote new experiences and learning, leading to change or stability, through the persistence of the fundamental elements that compose social-ecological systems.

System memory and innovation are two other characteristics that relate to resilience and response diversity, through variation of options. Additionally, system memory and innovation are complementary, since together they develop novelty and promote learning of multiple strategies for coping with disturbances. As a result, system memory and innovation are important elements for the evolution of the system and, together with the components of the social-ecological system and the relationships between them, constitute the identity of the system.

"Both the number of actors (actors' richness) and the diversity of the abilities and skills that characterize their management capabilities (actors' functional diversity) are key determinants of the resilience of social-ecological systems to global change" (Grêt-Regamey et al., 2019, p.290). In fact, actor richness and actors' functional richness are important factors supporting ecosystem services. Multiple and complementary possibilities of response to pressures and of disturbance management raise social-ecological resilience; otherwise, the basin of attraction reduces, and system can shift to another state, according to the ball-and-cup model. However, if the difficulty is too strong, even redundancy fails to maintain a stable structure for the system.

Furthermore, diversity arises from various levels, which interact with one another according to the perspective of panarchy, increasing the complexity of reality. In this perspective, the importance of functional diversity in cognitive abilities to enhance sustainability depends on social and ecological complexity, whose understanding enables social component to make favourable collective decisions. Indeed, complexity needs to be acknowledged and analysed, considering that social complexity is established by objectives, knowledge fragmentation and degree of collaboration or competition, while ecological complexity is composed of diversity, stability and predictability. As a result, functional diversity is related to social-ecological complexity, leading to a relationship where "just as a functional diversity of traits increases and maintains the efficiency and stability of ecosystems, a functional diversity of intelligence increases the ability of groups to sustainably harvest resources, especially in degrading environments" (Baggio et al., 2019, p.8).

Moreover, different perspectives and experiences are important for coping with difficulties in complex contexts, widening the possibilities. Variety of options for responding to fluctuations helps persistence of the system and its services. In particular, there are different kinds of diversities, and they all need to be protected, because they have decreased in the past centuries, challenging adaptive response to changes. For example, biodiversity sustains adaptation to environmental variability, fostering ecosystem functioning and human well-being, while diversity of knowledge and culture sustains social goals. Indeed, monocultures and simpler ecosystems are less likely to be resilient to disturbances, because their reduced diversity increases the risk of rapidly changing their state when they encounter adverse circumstances.

On the other hand, from a global perspective, modularity helps social-ecological resilience, since the subdivision in groups identified according to space, time or organization, minimizes transmissions. In this sense, it is suggested to create small-world networks, where connections are proximate between subpopulations, which remain relatively independent, but are never too loosely connected, ensuring an adequate level of openness. Modularity also fosters tightness and rapidity of feedback loops, which can increase cooperation or greed, taking advantage from the system. For this reason, social norms aiming at equity are essential in a common well-being perspective.

## 3.4 Resilience of social-ecological systems as sustainability

Ecological sustainability can be defined as "the natural limits set by the carrying capacity of the natural environment (physically, chemically and biologically), so that human use does not irreversibly impair the integrity and proper functioning of its natural processes and components" (de Groot et al., 2000, in de Groot et al., 2002, p.395). In this context, carrying capacity describes the maximum level of resource use and human population growth that the environment can support. When this limit is reached, the growth stops and starts decreasing, by rebalancing with renewed availability of resources. Resources on the planet are not infinite, because the planet itself is finite, and everything changes and evolves reorganizing in response to this limitation. Currently, the Earth is struggling as human population continues to grow, requiring more resources, which are not unlimited and are therefore gradually declining. Societies are resource dependent, relying on single resources or whole ecosystems concerning resources. Thus, social-ecological systems shape the sustainability of their development, which is linked to their resource utilization. In various cases, resource decline is also due to the human "insatiable desire to produce and consume" (Walker and Salt, 2006, p.4). This can happen consciously or unconsciously, due to a lack of knowledge about ecosystems and effects of human activities on them.

Given these considerations and reconnecting with the concept and theory of Gaia, it is possible to understand that the true principal problem is human behaviour, and that this needs to change if human trajectories are to be sustainable. Gaia will always adapt and survive anyway, evolving and transforming, but human life on Gaia may come to an end. This underlines the responsibility of human action for future perspectives.

Focusing on human activity from the social-ecological perspective on sustainability, economy emerges as an important component, together with humans, who are referred to as agents, and environment, which includes both built and biological elements. Economy and human society are subsystems of the biosphere, which they shape through the globalized rapid growth, urbanization and technologization, which have strongly increased the influence of human dimensions. Consequently, from the point of view of creating sustainable trajectories, both the economy and society should be reconnected to the biosphere so as to preserve its functioning.

Such considerations are also reflected in the 17 Sustainable Development Goals, which are founded on biosphere maintenance and are distributed across the domains of biosphere, society and economy, as shown in Figure 12.


**Figure 12. The global goals for sustainable development (Folke et al., 2016, p.5)**

In this figure, the different objectives have been associated with one of the three domains. At the same time, the domains are interconnected, because the positive outcomes at one level are enhanced by the favourable effects of progress in other domains. Indeed, in this representation, the biosphere constitutes the basis for societal and then economic development, linking their interrelated effects to the achievement of objectives. In other words, in order to follow a given sustainability goal, it is essential to focus on the connectedness between humans and biosphere, acknowledging that biosphere stewardship is fundamental. In fact, it is not possible just to consider human well-being, nor to believe that technologies will solve environmental problems. Commonly, physical infrastructures are built in response to risks and climate change consequences, but at best this will just mitigate the problem, without solving it.

Furthermore, biosphere stewardship requires interactions between various levels, context, actors and institutions, towards a holistic engagement aimed at innovation and learning. This is intended to build synergy between human action and the environment, in respect of its functions and services. In essence, "it is high time to reconnect approaches and perspectives on development to the biosphere foundation" (Folke et al., 2016, p.9). Indeed, healthy environments are connected to the development of well-being, acknowledging the effects of ecological challenges and the ways to deal with them, from both social-ecological and socio-psychological perspectives on resilience. This may lead to negative emotions and feelings, which need to be processed in order to promote constructive action. Proactivity develops individually, but especially within the community, by encouraging sustainability through organizations and leadership.

Through reconnection with the biosphere, it is possible to develop bottom-up approaches to sustainability that engage people's collaboration through the consciousness of their responsibility, without imposing the change. Indeed, stewardship is oriented towards caring for something for which everyone can feel responsible.

Moreover, from the point of view of methodology, sustainability approaches for ecosystem stewardship focus on vulnerability reduction, fostering social-ecological resilience and transformation to support desirable conditions in uncertain contexts. Considering vulnerability reduction, it must be recognized that sensitivity to risks contributes to individual vulnerability. Therefore, reducing vulnerability requires identifying risks, as well as decreasing sensitivity and exposure to them. Successively, social learning fosters resilience and reduces vulnerability to known stresses, by involving variations in capitals (natural, built, human and social) and social-ecological interactions.

In addition, in sustainability analysis, complex adaptive systems science (CAS) (An et al., 2025) declines an approach which has increasingly been followed. In particular, CAS provides a framework that also highlights the role of agents, which are characterized by specific traits and by possible actions that evolve in response to contextual circumstances. CAS can identify the interactions among agents of different levels or locations, analysing a hierarchical perspective, and can identify autonomous and heterogeneous actions within the system. Furthermore, actions influence other actors across time and space, as observed in social-ecological systems.

Collective action and cooperation between people from different places are fundamental for facing environmental change and sustainability challenge, given that everyone draws on common resources. Communities living in various places are characterized by cognitive diversity and their cooperation is sustained by high general intelligence and social intelligence, two cognitive abilities of vital importance. General intelligence deals with the understanding of ecological system and its rules, while social intelligence is connected to the theory of mind, where the individual is able to picture others' beliefs or intentions. Groups with higher levels of social and general intelligence are more likely to cooperate in order to sustain resources, because they understand the need for resource protection through the activation of general intelligence, while social intelligence fosters a common aim and helps monitor others' behaviours or needs. Consequently, it is easier to reorganize and negotiate when available resources are limited. Otherwise, when theory of mind and social intelligence are at a low level, everyone tends to act to increase their gain, overexploiting and degrading resources without preserving them for the future.

# Chapter 4. Social-ecological and socio-psychological assessing of resilience in educational contexts.

According to Quinlan et al. (2015, p.679), "resilience assessment involves a process of identifying how resilience is created, maintained or broken down", across several dimensions and levels, concerning both ecological, social and psychological components. The combined social-ecological and socio-psychological perspectives highlight how human beings and their environments are strongly interrelated in resilience analysis. Human well-being relies on the services and functions provided by socio-ecosystems, which are, in turn, influenced and shaped by human actions. This reciprocal influence must be recognized, together with the various consequences and implications that are connected to the complexity of the systems in the broader context. Thus, the social-ecological and socio-psychological perspectives are central in the assessment of resilience, through approaches that refer directly to the complexity and the multiple interconnections that characterize social-ecological systems and socio-psychological dimensions. Furthermore, complexity is enhanced by the dynamism of the resilience process, which constantly evolves over time.

Resilience analysis is generally a variable composite of procedures for assessment (a qualitative and quantitative process of gathering, analysing, and interpreting data) and measurement (a quantitative process of assigning a numeric value to data). This variability reflects its definition as "an emergent property that applies in different ways and in the different domains that make up your system" (Walker & Salt, 2012, in Quinlan et al., 2016, p.677). According to Keck and Sakdapolrak (2013, p.13), "resilience is best understood as a concept *in the making*" because there are not yet clear operationalizations or measures for this concept. For Wilson, (2013, p.228) resilience can be considered a "plural discourse rather than a discrete concept". Indeed, resilience is often referred to as a metaphor rather than an empirical and operationalizing concept in a specific system, particularly in terms of the difficulties and limitations encountered in measurement.

Thus, while resilience is an increasingly popular and widespread concept, it is not associated with a single clearly defined quantitative measurement or qualitative assessment. This issue is connected to the multiple definitions of resilience that can vary according to domains and disciplines, including psychology, society, economy and community, giving rise to different nuances in its definitions. These distinctions constitute a plurality that is essential for understanding the complexity of systems, which is reflected in the multiple existing methods, models and metrics for quantitative and qualitative analysis of resilience.

According to Quinlan et al. (2015, p.677), for the purposes of establishing the meaning and analysis of resilience across the multiplicity of definitions, methodologies and aims, in both measuring and assessing "it is important that: (i) the approach aligns with how resilience is being defined, (ii) the application suits the specific context and (iii) understanding of system dynamics is increased". Thus, given the various existing definitions of resilience, it is essential to specify the definition adopted. In general, resilience is considered as "the capacity of a system to undergo disturbance and maintain its functions and controls", so that its measurement and assessment focus on "the magnitude of disturbance the system can tolerate and still persist" (Carpenter at al., 2001, p.766). Rather than just maintaining stability, resilience is ability of the system to return to equilibrium. In this sense, resilience is preserved if the system remains within the boundaries of its domain of attraction. Otherwise, it changes its identity.

Resilience analysis must allow for a specific analysis of the characteristics of a given situation. For this purpose, it is essential to fully decline the object of the analysis, firstly focusing on resilience "to what" and "of what". In this way, the chosen definition of resilience specifies the aim, as well as the criteria to quantify and qualify resilience, to explain why and how it should be measured or assessed. In particular, the expression "to what" conveys the description of what the system is resilient to, concerning the difficulties it can experience and their drivers. On the other hand, the expression "of what" refers to the regime of the system identified as the one resilient to the disturbance.

In addition, the definition of resilience in terms of "of what" and "to what" clarifies the level of analysis in relation to temporal, social and spatial scales. The temporal scale considered can be extended to a greater or lesser extent and helps to distinguish the components of the system as fast or slow variables. The definition of the spatial scale is equally important, since the resilience of a region can be enhanced by resources coming from outside. Eventually, this may lead to issues for resilience at the broader spatial level if the displacement concerns several resources.

Overall, these considerations are universally applicable to any type of resilience assessment, guiding the research with some questions to delimit the scope of investigation and the subsequent outcomes. In this chapter, social-ecological and socio-psychological resilience measurement and assessment will be developed across their various dimensions, revisiting the resilience analysis proposed in the previous chapters through an examination of tools, frameworks, principles and methods associated with in the various systems. This analysis will be progressively directed towards the inclusion of complexity in the assessment of ecological, social-ecological and socio-psychological resilience. In conclusion, a part will be specifically dedicated to the socio-psychological resilience of children in educational contexts.

## 4.1 Ecological resilience assessment

The functioning of all ecosystems is based on interactions between components and is distinguished by measurable outputs such as diversity, size, growth and composition. For the purposes of analysing ecological resilience, it is important to define the structure and the function of the system, and how these can be affected by disruptions. Subsequently, it is necessary to measure the output of the system by using metrics that are adequate for the appropriate level of organization identified.

The metrics that have characterized ecological resilience assessment can be grouped into three categories (Ingrisch & Bahn, 2018, p.3):

1. Metrics that define the consequences of a disturbance on the system considering its state before the disruption.
2. Metrics that define the recovery from disturbance considering the state before the disruption.
3. Metrics that define the recovery from disturbance considering the impact linked to disturbance.

All the metrics included in these categories rely on different approaches to calculation and equation, so that it often becomes difficult to compare the results. To compensate for this limitation, Ingrisch and Bahn proposed a framework that attempts to unite the measurement and assessment of resistance and recovery of a system, identifying a bivariate space delineated by "the normalized impact of disturbance and the normalized recovery rate" (Ingrisch & Bahn, 2018, p.4). These normalizations are delineated in reference to the baseline of the system and are declined according to the situation preceding the disturbance. The analysis of the normalizations and their relationships allow for the identification of the time implied by the system to recover and the global accumulated loss during recovery. Indeed, each relationship between impact and recovery rate characterizes a unique qualification of the resilience of a precise system and is represented by a position in the bivariate space.

Another model proposed is CUSPRA (CUSP Resilience Assessment) (Sguotti et al., 2024), which is based on the identification of tipping points and the distance of the system from them. The CUSPRA model is linked to the Stochastic cusp model, a mathematical model developed by the mathematician René Thom, focusing on the theory of catastrophes. In the visual representation of the model, the tipping point constitutes the base of a cusp, resulting from the interaction between two stresses that lead to the tipping point. To apply the model, first a temporal series that represents the given system or population is selected. Then, the cusp is created using the two variables considered, making it possible to perceive the distance of the system or the population from the tipping point, which corresponds to its resilience. Finally, it is possible to analyse the evolution of resilience over time, by examining the proximity or distance of the system from the tipping point.

Although the CUSPRA model assesses resilience by quantifying and perceiving the variations of the concept, it is based on a simplification of the complexity in a given moment, because it is not predictive and only two stressors can be considered, while many more are present. Alternative approaches can focus on quantifying changes in the ecosystem structure, but this type of analysis is also limited because it does not consider the functioning of the system. Therefore, other approaches have been developed that aim to focus on quantifying resilience in the ecosystem functions, while assessing the functional resilience of the system and its interdependence with the composition and structure of the system.

Overall, research trends encompass different contributions and focuses related to ecological resilience, which are classified in the diagrams in Figure 13, that illustrate the objects of analysis of twenty-nine manuscripts.

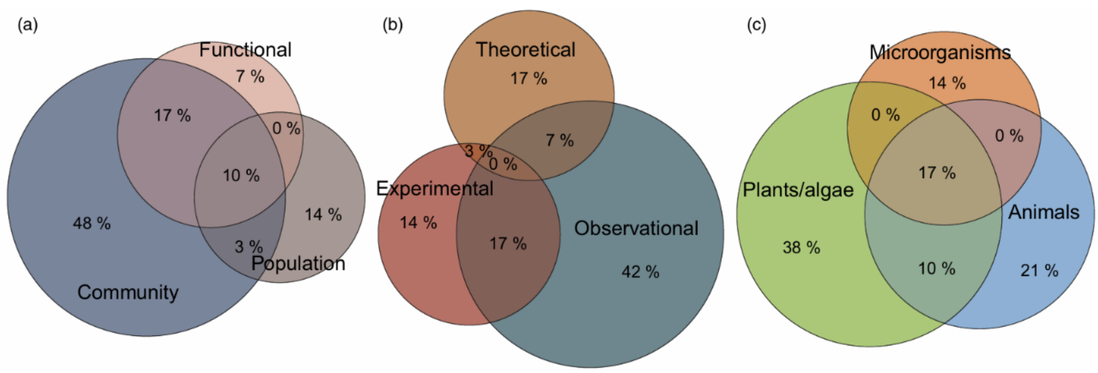


**Figure 13. Venn diagrams showing the proportions of the domains of operation of the studies considered (Capdevila et al., 2021, p.3105).**

The proposed categorization is referred to three main features: "the ecological subdiscipline, the approach and the system through which the authors study resilience"

(Capdevila et al., 2021, p.3105). Through the data represented in the diagrams it is possible to identify some important trends in ecological resilience research, such as the predominance of the community subdiscipline and the widespread use of observational approaches. This reveals an increased interdisciplinarity, which reflects in the consideration of multiple levels of organization, the integration of different approaches and various components of the system. New levels of research are emerging, detached from the uniquely theoretical analysis of the first studies on ecological resilience.

In conclusion, referring to current research, there are still many challenges that can be addressed for a better understanding and assessment of ecological resilience. One of these challenges concerns the development of predictive approaches capable of anticipating the potential consequences of system change. Furthermore, additional progress is required to facilitate comparisons among studies, which could be provided, for example, through a global assessment framework that should include shared tools or factors that can convert the metrics.

## 4.2 Frameworks for social-ecological resilience assessment

Initially, the quantification of resilience in social-ecological contexts was based on the distance of the system from a threshold, without specifying the range of desirable distance or the need for adaptation or transformation. This quantitative meaning is particularly emphasized by the interpretation of the word "resilience" whereby it is considered "a clearly specified and delimited stability concept" (Brand & Jax, 2007, p.8).

More recently, resilience assessment has increasingly incorporated the concept of complexity. The Resilience Alliance identified a series of steps for assessing resilience in social-ecological systems, which characterize the system according to its complexity "including its scale, key issues of concern, dynamics such as potential tipping points and ongoing interactions, and governance systems" (Resilience Alliance, 2010, in M. E. Krasny, 2020, p.213).

For the assessment of social-ecological resilience, one of the best-known frameworks is the *Resilience Assessment Workbook for Practitioners*, updated by the Resilience Alliance in 2010 (Enfors-Kautsky, 2021, p.2). This framework helps to understand the system's dynamics by analysing the main aspects characterizing them, such as system scales and boundaries, adaptive cycles and thresholds. The workbook can also offer recommendations about management and interventions based on the results obtained from its application. In practical terms, the framework provides tools that can also be utilized by non-scientific users, giving them information about system dynamics. However, its utilization follows a technical approach that, according to Enfors-Kautsky, is not supported by adequate guidelines.

Other frameworks have been published for the assessment of social-ecological resilience, proposing tools, scales and indicators with a focus on a specific field or feature. Indeed, in the recent developments emerges “a proliferation of different resilience guides”, where to identify some approaches that are closer to the aim of operationalizing resilience for sustainability by considering complexity and transformation. According to the research conducted by Enfors-Kautsky and her colleagues, among the multiple works published on this topic, only some of them are characterized by an innovative perspective aimed at sustainability (Enfors-Kautsky, 2021, p.3):

- The Companion modelling (COMMOD), which is a participatory model that focuses on the quality of the process and the complexity of problem solving.
- The “transition towns” movement, which considers both the local scale and the global scale together with their reciprocal influences.
- The “change labs” approach, which focuses on human agency and transformation.

These models belong to a set of approaches that are attempting to align the research with complexity and are currently growing and improving. For example, the Wayfinder framework has been developed, grounded in complexity thinking for social-ecological resilience in sustainability perspective. Indeed, the Wayfinder aims to facilitate collective change and foster planning for strategies that can lead to sustainable action. This framework is composed of five phases, as detailed in Figure 14, and helps understand the dynamics of the system, by promoting resilience thinking for sustainable agency, which is particularly enhanced by the last two phases. Indeed, the Wayfinder addresses operationalization and intervention, that, in these phases, implement the interaction about change narrative introduced in the first phases.


**Figure 14. Wayfinder iterative process of five phases (Enfors-Kautsky, 2021, p.10).**

Within the existing multiplicity of models and approaches, it is still not possible to identify general principles universally valid for qualifying social-ecological resilience, only a focus on specific aspects or elements of resilience. For example, seven principles have been defined according to the resilience of ecological services in social-ecological perspective. Biggs and colleagues grouped these principles into two categories: "generic SES properties and processes", which refer to the management of social-ecological systems in achieving desired objectives, and attributes that "focus on the way SES are governed" (Biggs et al., 2012, p.424), which provide guidance to set goals for management.

The first group is composed of three principles (Biggs et al., 2012, pp.425-432):

- Maintain diversity and redundancy at every system level, which relates to the observation of variety, balance and disparity as basic aspects for adaptation, which is obtained through mechanisms of compensation. Diversity and redundancy need to be balanced for an adaptive desirable outcome. Indeed, if their level is too low the system may increase its fragility, because of the limiting response options. On the other hand, excessively high levels of diversity and redundancy can cause difficulty in management and coordination within the system.

- Manage connectivity and interactions between all components of the social-ecological system, supporting the exchange of essential materials and information. Considering these characteristics, the presence of several links and stronger connections can enhance resilience. However, connectivity must be equilibrated, since higher levels of connectedness facilitate the rapid diffusion of disturbances and spread homogeneity.
- Manage slow variables and feedbacks that shape the fundamental structure of the system and its dynamics. Slow variables can be ecological or social and are related to the regulation of the system over time. Feedbacks are linked to system changes and can either strengthen or disrupt them. Monitoring slow variables and feedbacks is important, because it can prevent regime shifts of the systems.

The second category is composed of four principles (Biggs et al., 2012, pp.432-439):

- Foster an understanding of social-ecological systems as complex adaptive systems, which are characterized by collective behaviour and dynamicity. The acknowledgement of these qualities supports the identification of more appropriate management strategies for the system.
- Encourage experimentation and learning at both the individual level and at the social level. Experimentation and learning, together with monitoring, compose fundamental aspects of adaptation and transformation. Indeed, monitoring is necessary to balance the effects of experimentation and learning, as it is not clear which direction they should take in face of continuous changes that shape reality.
- Broaden participation as "active engagement of relevant stakeholders in SES management and governance" (Biggs et al., 2012, p.436), which improves the interpretation of circumstances. Anyway, not all forms of participation at any condition lead to desirable outcomes. In fact, positive effects depend on participants, their contributions and the context in which they act, including institutional settings.
- Promote polycentric governance systems, in which several authorities operating at different scales make decisions within a nested organization. For efficient functioning, the scales of governance should match the scales of problems originating among ecological services. In addition, trade-offs need to be negotiated between different components of the system, to ensure a governance that sustains all the other principles.

Furthermore, as represented in Figure 15, the seven principles are organized along two axes. The first axis recalls the previous classification between resilience of the social-ecological system and its governance, while the second axis highlights whether the principle focuses on system structure or dynamics.

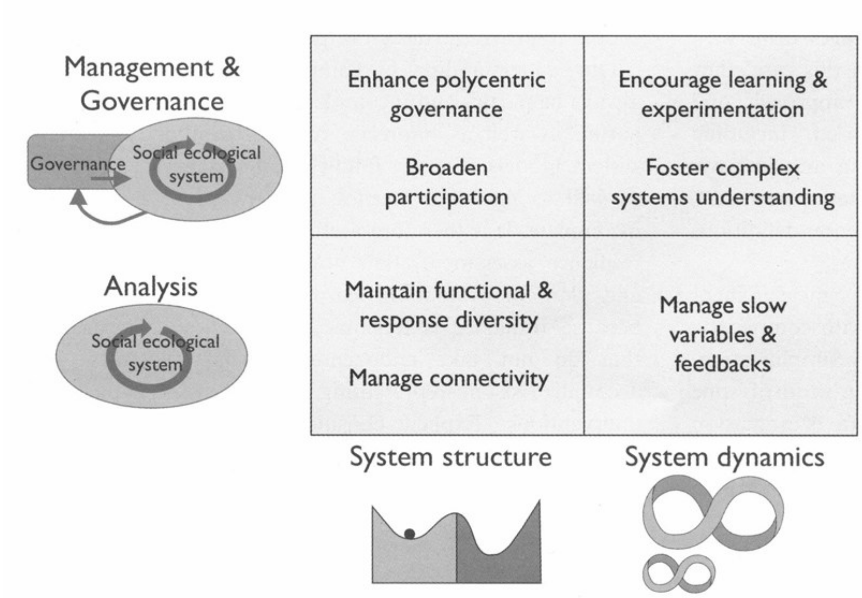


**Figure 15. Subdivision of the principles for enhancing resilience along two axes of focus (Quinlan et al., 2015, p.684).**

In general, considering operationalization, the principles describe strategies for social-ecological resilience that can be combined, since they are complementary and interrelated. All the principles are interdependent and must be interpreted according to specific situations to be able to assess whether they lead to positive outcomes or to a resilience reduction. Indeed, an important issue connected to the assessment of resilience is the specificity of the context in which the analysis applies.

To achieve this purpose, further studies are required to determine the conditions under which every principle produces positive effects, either for general resilience or specific resilience, which highlight an approach specifically linked to the context or one largely detached from it. The formulation of these seven principles attempted to follow an intermediate solution, promoting a moderate solicitation towards context sensitivity, while avoiding context dependence.

The coexistence of general and specific approaches to assessment raises another issue that consists in balancing the need for simplification to obtain clear results with the holistic nature of the social-ecological resilience perspective, including the dynamics, functions and interactions of the complex system. In any case, both general and specifical definitions are valuable and interdependent.

Furthermore, this issue extends to a broader point of view, including the cross-scale and multidisciplinary dimensions. In fact, there has been limited exchange between disciplines, domains and levels regarding the measurement of resilience, leading to difficulties in comparing results. For a better understanding of social-ecological systems in relation to resilience assessment, the indicators should be specifically declined according to the situation under examination. Then, if the indicators are clearly and hierarchically defined, the results obtained from this specific analysis can be compared with those emerging from other cases. In this way, it becomes possible to decline common properties of resilience, which would help the analysis across cases.

In any case, researchers believe that the understanding of complex adaptive systems, as well as their resilience measurement, will always inevitably be partial (Quinlan et al., 2016, p.683). For this reason, it is better to focus on qualitative assessment, rather than quantitative measurement, as it allows the analysis to be uncertain and balances this uncompletedness with further revision and monitoring. The characteristics of uncertainty and the progressive nature of analysis are consistent with the nature of a complex system, given its dynamic changes over time. However, the seven identified principles have attempted to preserve a certain level of coherence between approaches with validity for both measurement and assessment of social-ecological resilience.

### 4.2.1 Surrogate indicators for resilience assessment

Research can also focus on variables that can be surrogate indicators that can be used to approximate complex, difficult-to-measure social-ecological resilience factors. In this way, rather than attempting a general analysis of resilience, specific surrogate indicators can bring information about it because they are integral characteristics of it.

One indicator that can be considered is response diversity. A reduction in response diversity results in decreased functionality and increased vulnerability to difficulties. Response diversity can be assessed, although its impact varies according to the context and usually declines qualitatively because of its subjectivity. For example, diversity can be assessed through a social-ecological framework based on pathway diversity, as presented by Lade et al. (2020). According to their theory, higher pathway diversity corresponds to increased resilience, where a pathway is referred to as "a temporal sequence of actions taken by an agent or agents and the associated changes in the social-ecological system in which they are embedded" (p.4).

Furthermore, this allows for the consideration of decisions in relation to the availability of actions, with the aim of maintaining or increasing social-ecological resilience.

Indeed, actions contribute to resilience only if they do not limit future availability of other actions. This availability of actions depends both on external resources and constraints coming from society, and on internal factors such as individual knowledge and motivation. However, in this framework, pathways are considered together with the effects of actions on the system and the consequent impact on actions' availability. In this sense, the processes of interrelated feedback are included, in connection with diversity. Diversity is an important element for resilience across disciplines and levels, encompassing response diversity and functional redundancy. Consequently, diversity can be used as a parameter for resilience assessment, leading to significant results, as it corresponds to one of its main features.

In concrete terms, the measurement of pathway diversity involves a quantification of the pathways for a specific time span (variety), eventually specifying the weight of each pathway regarding their feasibility or contribution to adaptation (balance). For an operational version of this framework, it is possible to refer to a stylized mathematical model based on causal entropy. In any case, further research is needed to expand the possibilities of this framework and to improve its tools.

Another surrogate of social-ecological resilience that can be considered for measurement is system identity (Robinson & Berkes, 2010, p.337), which refers to system components, their interactions and elements of continuity or innovation. Cumming et al. (2005) also consider identity an important element for an explanatory framework for measuring resilience. They recall the main elements of identity definition, specifying that components of the system include objects, agents and entities that are part of the system, characterizing both social and ecological elements. Relationships underlie the connections between components, such as nutrient cycles or interactions between people. Innovation refers to sources that promote change and can be represented by diversity, learning or development of new technology. Finally, continuity is described by the cohesive maintenance of the system structure over time and space, and is reflected, for example, in system memory and knowledge.

In this analysis, the essential components and aspects of a system's identity can change, while still maintaining the underlying attributes over time, as they respond resiliently to changes internally and externally driven, while other aspects continue to vary and adapt. The analysis can relate these elements to thresholds and drivers, to consider the maintenance of key aspects and the effects in case of their variation. In particular, the comparison of these elements with thresholds aims to the explain "how resilience is being lost" (Robinson & Berkes, 2010, p.348). Furthermore, this approach enables stakeholders to define alternative stable states, supporting the traditional structure while allowing some evolution, without modifying the key elements.

For assessing the maintenance of identity, it is first necessary to define the identity of the system and the amount of change it can face before identity loss occurs. In this way it is possible to monitor the development of social-ecological resilience together with the development of identity. Indeed, if identity is lost, the system entails reduced resilience; on the other hand, if the identity is maintained even across scenarios, resilience is notable. It is possible to define plausible scenarios, where the system changes while still maintaining its identity or completely transforms, to evaluate system outcomes and analyse the conditions under which it would be better for the system to restore resilience through a state shift. For each alternative scenario, a level of probability should be assigned, together with an examination of uncertainty and identity maintenance.

In general, the main interest of identity analysis is to examine change trajectories of identity, monitoring key variables and alternative pathways.

### 4.2.2 Analysis and future directions

In the light of the multiplicity of methodologies and measures available for the assessment of social-ecological resilience, Ruiz-Agudelo and Cortes-Gomez (2026) propose a review aiming to understand the trends in research and the coherence with the seven principles previously described. The review considered 146 documents on the subject published since 2011, classifying them according to the study characteristics and their reference to the seven principles. In fact, the inclusion of more principles was associated with a more comprehensive knowledge of the system. On this purpose, the results of the review highlighted that 77% of the studies addressed three to five principles "most commonly focusing on managing slow variables and feedback, managing connectivity, maintaining diversity and redundancy, and fostering complex adaptive systems thinking" (p.8). Only 12% of the studies addressed all the seven principles, revealing a lack of systematization of all the principles, that slows the understanding and subsequent action for social-ecological resilience.

For further classification of the studies, the authors analysed them according to their methods, such as qualitative approaches or the use of indices and indicators. Then, each study was reconducted to a specific domain of resilience, also defining the object (resilience of what?) and the disturbance (resilience to what?). The results showed a prevalence of interest in terrestrial ecosystems, ecosystem services and social-ecological systems in relation to their resilience to climate change.

Focusing on the results of the complexity analysis, 47% of the studies concerned ecological resilience assessment, with reduced consideration of the social component, underlining a disconnection between the theoretical aims and the measurement and assessment objectives. This is followed by studies concerning communities, which focus on adaptive capacity, but usually do not include insights into the ecological component, reinforcing the disconnection between theory and measurement. Studies that use the hybrid Ecosystem Services Resilience Framework attempt to fill this gap by acknowledging the interconnections between the ecological and social sphere, but they do not adequately assess dynamic changes over time, and they tend to remain static. Finally, the examination of social-ecological resilience is usually conducted through indicators rather than system dynamics or complex models, suggesting that robust methodologies for assessment in this context are still missing. Given these considerations, the integration of different approaches may be a better solution for coping with the uncertainty, complexity and difficulty of measuring social-ecological resilience.

Furthermore, some researchers analyse the congruence between the theoretical conception of resilience and its assessment by examining the extent to which its main features are involved in quantitative measurement. For example, research conducted by Sanches et al. (2025) examined the inclusion of diversity and agency quantitative measurement by reviewing the identified studies. The presence of agency measurement was confirmed when the study employed metric tools for agents' capability to act, in terms of ability to manage skills and resources. On the other hand, the presence of diversity measurement was confirmed when studies specifically referred to the three diversity properties identified by Stirling: variety, balance and disparity (Stirling, 2007, in Sanches et al., 2025, p.6). From the results of the research, the operationalization of agency and diversity in the metrics of study is still rare, even though they are qualitatively recognized as fundamental features for social-ecological resilience, as discussed in the previous chapters.

In the light of these considerations, further development of research methodologies, especially in quantitative measurement, is necessary to increase the connection with the theoretical aims and key features.

## 4.3 Assessing the socio-psychological resilience of children in educational contexts

Social-ecological resilience is closely related to education, linking learning environments and society, thereby integrating psychological, communal and ecological dimensions. These interconnections highlight the complexity involved in understanding the dynamic reality that surrounds every individual and can be further analysed in educational contexts according to various points of view within the dimensions of socio-psychological resilience.

Before moving on to assessment approaches, it is necessary to examine and specify the roles that education can play in the field of resilience. Education has been identified as an important element in strengthening social-ecological and socio-psychological resilience, leading to various interpretations of its role in this context.

From a behaviourist perspective, environmental education can play an instrumental role, aiming to develop behavioural change and increase awareness of more sustainable lifestyles. In fact, in face of rapid environmental changes, educators foster forms of education that enhance resilient factors, promoting supportive networks. In this way, they help to counteract depressive feelings, and they contribute to the restoration of well-being, by focusing on resilience thinking, social capital and ecosystem services. In particular, the well-being of the system is achieved when survival and security are guaranteed, as they are basic components that also characterize sustainability.

Furthermore, education for resilience has been conceptualized as grounded in care for the future and respect for nature in order to preserve it. In this way, education emphasizes external effects of resilience, while it should also be connected to the inner dimension of the resilient learner, through the integration of "resilient learning and learning for resilience" (Garista & Pagliarino, 2020, p.110). This intrinsic view follows the constructivist position and critiques an instrumental idea of education for being prescriptive, a characteristic that is not suited for the unpredictability of the future, since it is not possible to define in advance the qualities of a sustainable society.

From the methodological point of view, intrinsic education focuses on the resilient learner, developing his critical reflection and autonomy while making decisions, together with an increased willingness to face learning challenges. Following these considerations, learning is open-ended and education should emphasize sensitivity, responsibility and collectivity in order to discern among all the possible pathways that are generated according to the uncertainty of the future. In this case, education builds and fosters adaptive capacity of learners, underlining the process and the educational experience, whereas an instrumental idea of education highlights the product in relation to environmental care.

It must be specified that both the intrinsic and the instrumental approaches emphasize the individuality of learning, while there is also a third perspective, based on social-ecological dynamic, that addresses social learning and shared knowledge. This approach refers to adaptive co-management, which constitutes the basis of a resilient society considered as a whole, where diversity and plurality are fundamental, and each component declines according to the specific context.

Another perspective considers transformation, where human well-being needs to develop in conjunction with ecological, economic and social components, within a global dynamic. The educational perspective, like the ecological and psychological ones, promotes the concepts of adaptation and transformation for social-ecological and socio-psychological resilience. In this respect, Freire, who developed an approach in which learning is aimed at caring for the natural and social environments, recognizes that "we are transformative beings and we are not destined to accommodate ourselves to what exists" (Freire 2005, in Garista & Pagliarino, 2020, p.102). In this sense, resilience is connected to a democratic conception in the school context, fostering connections and dialogues to strengthen communal well-being in a multi-dimensional perspective, and considering collective transformation as the driving factor to achieve it.

Sterling (2010, p.520) points to a paradox of education, since it "is seen as a preparation for the future, but it grows out of the past". Indeed, the unpredictability and the complexity of the future reveal the limitations of an approach based on the past, because it cannot respond to present needs. Practices of active learning and authentic experiences are best suited to promote adaptability, by stimulating the sense of self-efficacy. For greater positive effect, environmental education should be promoted beyond the forma school educational level, including several organizations in a nested perspective of partnership and stewardship for governance.

Furthermore, it must be recognized that socio-psychological resilience in educational contexts does not rely only on individual responsibility, as the organization of the environment has a significant influence on everyone's behaviour. This consideration is related to socio-psychological resilience, because, depending on the availability of resources and institutional organization, an individual can be more resilient or less resilient. Indeed, the resilience of the child can be externally supported by the opportunities offered within school settings, which foster key elements connected to individual resilience, such as capacities, skills, and talents.

"At the core of most of these effective school qualities are positive relationships and expectations that communicate to children and their parents a caring and invested community for learning" (Masten, 2014, p.223). Supportive school settings entail positive long-term consequences on individual development, especially for students who experience adversities and lack support outside school. Moreover, teachers are responsible for maintaining such a supportive climate by promoting resilience through "providing a student caring and support, high expectations, and opportunities for participation and contribution" (Masten, 2014, p.229). Also, teachers can foster students' resilience by offering a positive role model that influences coping and adaptive strategies.

On the other hand, considering socio-psychological resilience as a characteristic that emerges only from individual effort leads to exclusive emphasis on personal responsibility, reducing or eliminating the significance of the support coming from institutions. This misinterpretation would justify the lack of support, on the assumption that everyone should develop resilience autonomously.

In addition, an alternative perspective on resilience in educational contexts focuses on the experiences that children can have within school settings. For example, students at school can experience stress, which is frequently associated with the results of personal goals, where social and emotional support can moderate the negative effects, by building coping strategies to enhance intrinsic resilience. Furthermore, other adversities can be experienced in school contexts, such as bullying, discrimination or harassment. In fact, at different levels, these adverse experiences may begin processes of building resilience that could be supported by school setting.

Finally, within research on educational resilience there is no agreement on how to measure or assess reasons for difficulties or abilities for adaptation in the school context based on learning outcomes. The main aspects evaluated in such measurements or assessments are based on self-control skills, social skills, self-efficacy, learning and knowledge, all considered fundamental components for a resilient outcome.

### 4.3.2 Frameworks for assessing socio-psychological resilience of children

Windle et al. (2011, p.2) affirm that defining psychological resilience as "the process of negotiating, managing and adapting to significant sources of stress or trauma" enables different methodologies and scales can be considered.

In general, three main strands of research in the assessment of individual resilience can be identified over recent decades, each with different objects of analysis. The first approach aimed at the recognition of positive developmental pathways, underlining the exceptional characteristics that emerged within a sample of individuals exposed to circumstances at risk. A second approach focused on the identification of protective processes in coping with adversities, successively also including promotive, compensatory and challenge processes. A third approach was phenomenological, introducing qualitative research methods to explore positive pathways after the experience of adversity.

Another distinction that can be specified for assessing socio-psychological resilience concerns the different directions of research, which identify various aspects that can predict socio-psychological resilience:

- Biological factors, but only if the stressful circumstances lead to a consequent positive development.
- Strengths and personal or social resources, whose effect vary depending on the exposure to stressors.
- Cultural variation in the processes that characterize resilience, as well as broader ecological factors.

These three study directions share a common aim in recent research, since they all seek to create a model that would be able to simultaneously take into consideration the individual level and the environmental level. In fact, initially, resilience in social systems was assessed by identifying the traits of "resilient individuals", then its analysis detached from the individual perspective and shifted towards "interactional processes in challenging environments" (Ungar, 2011, p.1). Following this change of paradigm, resilience can be better understood if analysed as a consequence of difficulty, rising as a quality of the social-ecological environment where the individual behaves, rather than as a purely individual property.

The aspects that foster a child's development have the same positive effect on their socio-psychological resilience. These aspects, for example, correspond to supportive caregiver relationships and narrative identity, which provide meaning and social cohesion. Additionally, the individual narrative identity is influenced by the community through historical experiences and culture, as well as by society through its organizations and policies. In this way, the assessment of resilience connects to family and community, expanding the perspective of examination, because individual behaviour depends on ecological interactions at microsystem, mesosystem, exosystem and macrosystem level. Indeed, the assessment and analysis of socio-psychological resilience should include both individual and collective contribution.

The Developmental Strengths (DS) model offers a perspective where children are shown to be able to overcome difficulties and achieve positive development, including the perspective of their future life. Indeed, this model identifies the intrinsic and extrinsic strengths that enhance individual resilience and well-being. Intrinsic strengths underline personal attributes like empathy and self-esteem, while extrinsic strengths refer to the settings where interactional exchanges happen and reflect positive relationships, for example within the family, at school or among peers. In particular, the three main areas that decline the variability for individual resilience are: "(1) personal attributes; (2) family characteristics; and (3) other external support systems such as peers, school, and the community" (Donnon & Hammond, 2007, p.451). On the basis of these considerations, the Developmental Strengths model has been created to assess individual issues across the growth span of time.

This multi-dimensional framework is introduced by a questionnaire (YR: ADS) for assessing protective factors and strengths in adolescents. Specifically, the strengths are identified as resilient factors and concern relationships between the individual and his family, peers and community members, investigating the positive interactions that can emerge. In addition, protective factors are linked to dimensions of self-perception, such as self-control and self-esteem, as well as to sensibility towards culture and society, referring for example to cultural awareness, empathy and caring.

The indicators of the questionnaire are organized into three parts and use a five-point Likert scale for responses. The first part is dedicated to the development of strengths connected to the resilience framework. The second part collects information on the frequency of potential indicators of negative outcomes, such as antisocial behaviour. Finally, the last part concerns demographic indicators. Every part is composed of indicators that are related to those of other parts, so that these reciprocal influences can result from the analysis.

Furthermore, seven out of the thirty-one strengths declined in the framework are addressed to school context, as shown in Figure 16.

| | |
|---|---|
| Commitment to learning at school | Achievement: Youth works hard to do well and get the best grades in school. |
| | School engagement: Youth is interested in learning and working hard in the classroom. |
| | School work: Youth works hard to complete homework and assignments on time. |
| School culture | School boundaries: School has clear rules and expectations for appropriate behaviors. |
| | Bonding to school: Youth cares about and feels safe at school. |
| | Caring school climate: School environment and teachers provide a caring climate. |
| | High expectations: School/teacher encourages goal setting and to do the best they can. |

**Figure 16. Part of the list with resiliency factors together with the corresponding developmental strengths and their description (Donnon & Hammond, 2007, p.452).**

The table shows that the developmental strengths encompass both the individual and the institutional perspectives, dividing responsibilities for individual resilience between the two.

Finally, the Developmental Strengths model demonstrates the connection between risky behaviours or outcomes and resiliency profiles of students, which quantify their coping capacities. Furthermore, this resilience framework can be applied to the examination of a specific aspect. Donnon and Hammond (2007) describe in their article that this questionnaire was used for the assessment of bullying in educational contexts. Specifically, the questionnaire was designed for adolescents and students of higher grades, from seven to twelve, but has demonstrated successful effects even on sixth grade students, proving its flexibility according to the various contexts analysed.

Studies of this kind highlight possibilities of intervention based on evidence that emerge from the analysis of the data collected, providing an ecological perspective of the issue investigated within the educational context. Anyway, extending the intervention beyond educational context would improve the effectiveness of the framework, through the inclusion of broader environmental influences. The school has a fundamental role to play in children's development "by providing the components or strengths they need to be caring and productive citizens in adulthood" (Donnon & Hammond, 2007, p.468), but also personal, social, cultural and economic components have a great influence.

Therefore, social and cultural factors are predictors of resilience, since they interact with individual development through the availability of resources that support its course. As a result, a Vygotskian perspective is increasingly seen as fundamental, by emphasizing that environmental influence is not only important, but also predominant. In fact, "the environment is even more critical to child development than a child's individual traits" (Ungar, 2011, p.4).

The assessment of resilience within psychological and social contexts is associated with the social-ecological perspective. The necessity for a holistic and multi-dimensional approach emerges, where several components are evaluated altogether with their interactions. For example, one of the frameworks proposed to assess resilience from the social-ecological point of view is PVEST (Spencer et al., 1997, p.818), which unites the multi-level influence represented in the ecological system model theorized by Bronfenbrenner and the individual's own perception. This perception is influenced by personal experiences, which are shaped by social and cultural contexts. The process described by these multiple influences affects the individual's behavioural responses and shapes their identity, while also being influenced by others' perceptions and, in turn, influencing them through individual actions.

In particular, PVEST represents a phenomenological variant of ecological systems theory and emerges as an intersectional approach for understanding life-course identity formation that critiques deterministic models, because they do not consider inequalities, nor their intersectional effects. In this case, the perspective must be multi-disciplinary and contextualized, considering environment, society and individuality. Socially and environmentally originated resources and opportunities are essential for the development of individual resilience and need to be examined, especially since their availability is not equally distributed among individuals.

This perspective is linked to the possibility of enhancing outcomes that lead to a distinction between "winners" and "losers", established by individual capital and habitus throughout the resilience-building processes. This raises another question: "resilience *in whose interest*?" (Keck & Sakdapolrak, 2013, p.14), an interrogative that highlights the fact that resilience is also politically determined, and that access to resources can be distributed in ways that either enhance vulnerability or foster resilience, by reducing or increasing social inequalities.

All these factors are reunited in the PVEST ecological resilience framework, which is at the basis of possible programs of intervention for building a supportive community. Moreover, the model is also effective for resilience analysis in educational contexts, focusing on individual perceptions while contextualizing them at a wider level. Indeed, in school settings, perceptions of peers and teachers constitute an important element of evaluation for understanding personal behaviour.

Furthermore, Bronfenbrenner's bioecological theory can be used as a framework for the assessment of community resilience to natural disasters, through an evaluation of people's recovery and persistence in face of adversity. In this sense, there are different levels at which resilience can be investigated, concerning individual, community, organization or ecosystem. The individual level is the simplest to analyse because higher levels progressively increase interconnections and relationships as their size expands, including more people and components. Then, community or social resilience is located in the macro level and can be assessed through indicators identifying variations from the economic, institutional and demographic point of view.

The nested consideration of all levels unifies the assessment of socio-psychological resilience through referring to both internal and external aspects affecting the individual. In fact, individual behaviours and responses are shaped by external influences from the levels, reflecting the interdependence between individual and communal resilience. The model can measure the effects of organizations and policies on both individuals and communities, even from a longitudinal perspective. The model estimates the nested influences that happen "across, between and within systems" (Boon et al., 2012, p.403), underlying the interdependencies between levels, that usually are analysed separately in resilience assessment. "The key idea is that community resilience then is promoted through adaptive capacity enacted by individuals who form various organizations that become mobilized in response to a disaster" (Boon et al., 2012, p.387).

Finally, in order to ecologically broaden the analysis of resilience development for well-being, four principles are identified, viewing resilience as a quality of the social and physical ecology where the individual lives (Ungar, 2011, pp.4-10):

- Decentrality, which underlies the shift of the locus of change from the child to the resources supplied by the environment for him. This principle claims the need for the analysis of child-context exchange over time, without considering the environment as secondary.
- Complexity, which highly reduces predictability and arises from the variability of environment, the individual and their interactions or reciprocal adaptations. This principle suggests the need to develop context-specific models and to be cautious in generalizing.
- Atypicality, which refers to a hidden form of resilience, since someone who has experienced harsh adversities may evolve alternative strategies to cope with them. In this sense, resilience manifestations could be unusual and not socially accepted, but useful for facing the situation the individual is experiencing. Over time, hopefully, strategies will vary becoming more desirable.
- Cultural relativity, which, as well as temporal and historical characterization, shapes the outcomes after difficulties.

### 4.3.3 Analysis and future directions

Given the multiplicity of measures, principles and scales that can be referred to in this research-field, systematization is necessary; yet various reviews have been published with this aim.

Windle et al. (2011) conducted a quantitative methodological review to identify the scales utilized for socio-psychological resilience measurement, establishing their psychometric rigor. In particular, the scale properties assessed are presented in Table 1, in which each property is associated with quality criteria assigning a score that varies according to the extent to which every item is satisfied.

| Property | Definition |
|---|---|
| 1. Content validity | The extent to which the domain of interest is comprehensively sampled by the items in the questionnaire (the extent to which the measure represents all facets of the construct under question). |
| 2. Internal consistency | The extent to which items in a (sub)scale are intercorrelated, thus measuring the same construct. |
| 3. Criterion validity | The extent to which scores on a particular questionnaire relate to a gold standard. |
| 4. Construct validity | The extent to which scores on a particular questionnaire relate to other measures in a manner that is consistent with theoretically derived hypotheses concerning the concepts that are being measured. |
| 5. Reproducibility | |
| 5.1 Agreement | The extent to which the scores on repeated measures are close to each other (absolute measurement error). |
| 5.2 Reliability | The extent to which patients can be distinguished from each other, despite measurement errors (relative measurement error). |
| 6. Responsiveness | The ability of a questionnaire to detect clinically important changes over time. |
| 7. Floor and ceiling effects | The number of respondents who achieved the lowest or highest possible score. |
| 8. Interpretability | The degree to which one can assign qualitative meaning to quantitative scores. |

**Table 1. Scoring criteria for assessing quality of resilience measurement (Windle et al., 2011, pp.3-4).**

According to these criteria fifteen validated measurement scales and four subsequent refinements were analysed, with the majority of them focusing on individual resilience assessment. The results showed that each tool demonstrated insufficient information and inability to significantly satisfy all the given criteria. In particular, most scales focus on the presence of resources and assets coming from community and family in order to foster resilient outcomes. Finally, only five studies reflect the complexity and dynamicity of resilience concept through an examination that crosses multiple levels.

This review highlighted a lack of scales for measuring socio-psychological resilience in children aged under twelve. Among the instruments identified, only the Resilience Scale of the California Healthy Kids Survey (Windle et al., 2011 p.16) is considered, evaluating children's perceptions of internal and external resources, but it showed poor results according to the quality framework described above.

Even among other questionnaires and programs examined by Inguglia and Lo Coco, (2013) in their study on resilience assessment, it is possible to find approaches mainly dedicated to children aged ten years and older, focusing on internal and external resources referred to the dimensions of the self, family, school, peers and community. Among these it is possible to find the Adolescent Resilience Questionnaire (ARQ-Revised) of Gartland et al. (Inguglia & Lo Coco, 2013, p.68) or the Individual Protective Factors Index (IPFI) of Springer and Phillips (Inguglia & Lo Coco, 2013, p.71).

These scales proposed refer to self-report questionnaires. However, an alternative strategy for assessing children's resilience, even in younger children, considers their adaptive behaviour from the point of view of the adults who know them well, such as parents, teachers and caregivers. For example, the Devereux Early Childhood Assessment Program (DECA) of LeBuffe (Inguglia & Lo Coco, 2013, p.70) is designed for parents and teachers of children aged between two and five years old, and evaluates initiative, self-control and attachment in the child, as well as worries about his behaviour. Similarly, The Devereux Student Strengths Assessment (DESSA) of LeBuffe et al. (Inguglia & Lo Coco, 2013, p.70-71) is designed for parents and teachers of children aged between five and fourteen years old through the analysis of their behaviours during the four weeks preceding questionnaire completion.

In this way, different responders can be investigated, and according to their characteristics, it is possible to identify the most suitable questionnaire or scale. However, there is no gold standard that can be preferred and the available scales reveal different limitations, especially when assessing younger people.

Given the lack of measures for children under twelve that emerged in the review of Windle et al., Hall et al. proposed a specifical review with the aim of filling this gap, by focusing on research approaches rather than qualifying the measuring tools. In particular, fifty-four measures were selected and divided into two categories according to whether they assessed socio-psychological resilience directly as a construct (Type 1) or as an outcome through resilience related factors (Type 2), defining two groups of nearly equal size. The data collected for each measure concerned "study characteristics (i.e., author, publication date and country of research), definition of resilience, methodology (i.e., participant characteristics, study design, outcomes), and the psychometric properties of the identified measure of resilience (i.e., reliability and validity statistics)" (Hall et al., 2024, p.2).

Examining the results of the review, from the point of view of characteristics, the most employed measures belong to Type 2 and include, in order of frequency, the Strengths and Difficulties Questionnaire (SDQ) and the Achenbach Child Behaviour Checklist (CBCL) (Hall et al., 2024, p.3). The respondent for most measures is the child, followed by parents and teachers or third-party reporters, and responses usually follow a Likert-style scale.

Subsequently, the psychometric properties of eighty-six articles were considered, generating variable results. In relation to reliability, 35% of the measures presented internal consistency within an acceptable range, while 78% of the articles did not report test-retest reliability. Among the studies considered, there were poor results concerning validity, since these results were missing for 58% of the measures.

Considering the components of the measures, 85% of them presented composite scores, subscales or total scores, assessing resilience directly or through its related factors, which can be referred to individual or social-ecological resources, as represented in Figure 17.

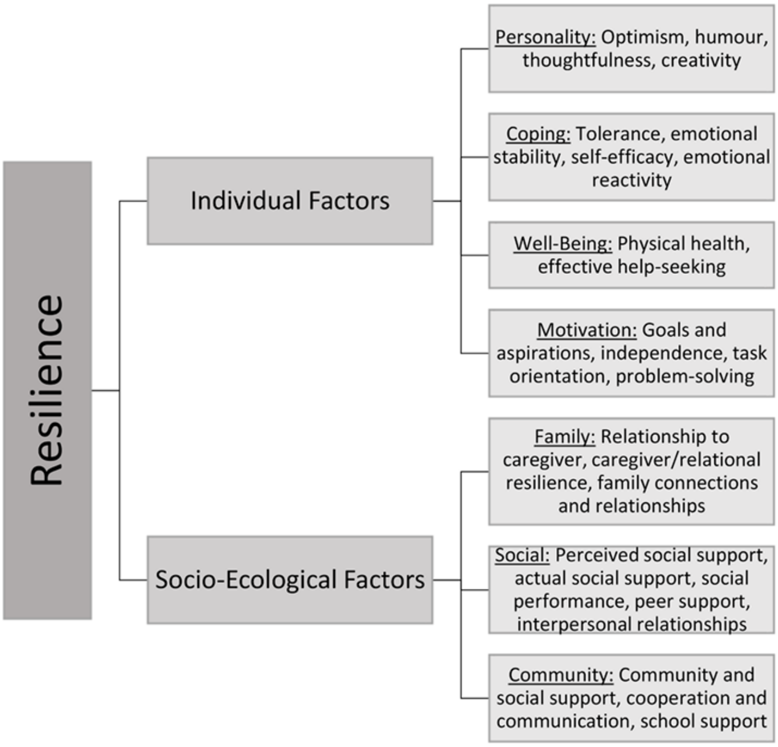


**Figure 17. Conceptual scheme of factors that can be considered for resilience assessment (Hall et al., 2024, p.8).**

There is broad agreement that multiple levels should be considered in its assessment, including both individual factors and social-ecological factors. However, among the studies analysed, only four approaches seem to follow this direction: "the Child and Youth Resilience Measure, Adolescent Resilience Questionnaire, Child Resilience Questionnaire, and Resilience Scale" (Hall et al., 2024, p.8).

Furthermore, data obtained through direct report of the children are considered valid when based on Likert-style scales, which should be adapted to the age of the children, through comprehensible language and a reduced number of point responses.

Some common critical issues tend to emerge among the tools and the methodologies adopted. Indeed, the tools utilized in the past decades for measuring environmental influences on individuals were not neutral and objective, because they were declined according to the dominant culture. Indeed, the scales identified for adolescents and children were based on resources coming from school, but they were declined according to western cultural norms. Therefore, perceptions of resilient outcomes are culturally determined and is not possible to find a universal measure, which makes it difficult to compare resilience across cultures. Even the context in which a questionnaire is administered may alter the results, producing a situational effect.

Furthermore, studies have been focused on identifying individual characteristics associated with socio-psychological resilience, in order to foster them. However, there are no special characteristics that define a resilient individual, since resilience can be observed in everyone, emerging as a common and ordinary process. Also, there are different possible pathways that may lead to resilience. Thus, it is not possible to identify processes or factors that are valid for its development in any case. Each situation needs to be examined specifically, considering individual responses connected with the social influences and the broader context where everything takes place.

Finally, children have encountered several adversities in recent decades and continue to experience them currently, with consequences for resilience that are reflected in educational environments. In this context, resilience is referred to as a complex process where both the capacity of the individual and the capacity of the system are important for supporting resilience. The measurement of this complex process remains challenging, as has emerged from reviews of resilience assessment tools. Indeed, most scales are usually connected to factors related to resilience, rather than resilience itself (Chmitorz et al., 2018, in Hall et al., 2024, p.2). These indirect indicators investigate the exposure to adversity and positive adaptation, including factors such as well-being and perception of stress, which are surrogates of resilience and therefore cannot provide data directly associated with resilience.

Additionally, "since a vast array of developmental processes and experiences can be examined as resilience, we must ask when research is truly studying resilience rather than specific constructs that may be implicated in resilience processes but do not actually constitute resilience themselves" (Lipscomb et al., 2024, p.2). Consequently, this risk can be avoided by considering studies that focus on processes rather than traits, specify the adversity examined and explain the outcomes assessed, so that the key features of resilience are respected and reflected in its assessment.

Indeed, other studies specifically refer to the coexistence of adverse conditions and positive outcomes for assessing socio-psychological resilience. In this case, difficulties and stress can be measured using single objective indicators or multidimensional indicators. However, it is important to acknowledge the complexity of the situation by recognizing the subjective impact of disturbances and life-stressors. Many scales are developed with this aim and, eventually, it is possible to assess difficulties by investigating different evaluators, multiplying the perspectives in order to provide a better understanding through the congruence or incongruence between the judgments of the raters.

Ultimately, for the assessment of positive outcomes, the focus should not concern the absence of disturbances, but rather the presence of competences and abilities, by examining factors across the various domains shown in Figure 17 within a multidimensional approach.

# Conclusions

Resilience is a polysemic concept associated with multiple definitions and widely applied across several domains. There is no agreement on universal definitions of resilience, as its meaning varies according to the dimension and the theoretical approach considered.

In this study, resilience is examined initially from an ecological and a socio-psychological perspective, integrating their conceptual meanings and their bidirectional interactions, thereby progressively moving toward a social-ecological dimension. This follows the chronological evolution of the resilience concept, starting from its origins in ecology, which inspired further studies in psychology, progressively integrating more disciplines towards a more comprehensive understanding of complex systems and reality. This approach based on plurality and multidimensionality is driven by the concept of complexity, adopting a holistic perspective based on the identification of both the components of complex systems and the relationships between them. Complexity profoundly shapes reality at every level, encompassing ecological, social-ecological and socio-psychological systems from local to global scale, leading to cross-scale influences described by the concept of panarchy (Gunderson & Holling, 2002).

Gradually it has come to be recognized that the study of ecological and socio-psychological resilience requires a progressive integration between empirical studies and analytic procedures, within an interconnected social-ecological framework. There is a profound connection between ecosystems and human beings, characterized by multiple cause-and-effect relationships, since humans depend on ecosystems services and natural resources, while ecosystems are simultaneously shaped by human activities. This complex reciprocal interconnection highlights the need to consider both ecological and social components, as well as their interactions, in order to improve understanding of natural and human phenomena. The analysis of these components in isolation would inevitably limit the results.

Among the various interpretations of resilience, it is possible to identify common features that characterize resilience across multiple disciplines. It is defined as a process composed of two dimensions that constitute its core meaning in every field of reference: the experience of disturbances and the consequent outcomes for ecological, socio-psychological or social-ecological systems. These elements have been examined from multiple perspectives by qualifying disturbances at ecological and socio-psychological levels and by analysing the functional or dysfunctional responses of ecological and social-ecological systems, through examining their relationship with tipping points, thresholds and the maintenance of the same stable states or system identity.

Another key feature characterizing ecological, socio-psychological and social-ecological resilience concerns its deep connection with dynamism and change, characteristics that together with those of unpredictability and uncertainty, underpin the concept of complexity. In this sense, resilience is a process that responds to dynamicity of the context by implying changing conditions, through adaptive or transformative responses to disruptions. Adaptation refers to adjustment that enables ecological and social-ecological systems to maintain their essential functions and remain within the same stable state.

On the other hand, transformation involves a shift to another stable state, following the crossing of critical thresholds. In social systems, transformation contributes to the development of individuals and communities, through social learning and social memory. In this perspective, changes are seen as opportunities for social systems, since they cannot return to the state that existed before the disturbance. Social systems can only transform, unlike ecological systems, that can bounce back at their previous state. Thus, human agency has a strong influence on the adaptive and transformative processes of resilience, representing a peculiar dimension of social systems. Agency also involves reflection on future action and its potential consequences, leading to transformation and evolution.

In socio-psychological contexts, the resilience process has been defined as a dynamic and continuous process of child development, rather than as a set of personal qualities fixed over time. An individual's resilience results from the interaction between internal and external resources, which both continue to change throughout time by shaping the socio-psychological resilience of the individual. In this sense, psychological resilience cannot be understood solely as the responsibility of the individual, focusing on internal resources such as coping, together with adaptive and transformative capacities. It also depends on the availability of external resources and the opportunities to access them.

These external resources for enhancing the psychological resilience of the child or the individual in general are located in a broader context, where informal and formal educational environments and organizations can facilitate individuals by offering opportunities for development. The individual sphere and the community sphere strongly influence each other, so that to understand the concept of complexity it is necessary to consider them both, together with their relationships. Resilience cannot be considered an individual property, as it is socially and ecologically determined through environmental influence.

In addition, diversity is another key feature of resilience across ecological, socio-psychological and social-ecological dimensions, highlighting the importance of maintaining biodiversity, response diversity and functional redundancy. Diversity, through compensatory processes, enhances resilience at every level, by increasing a system's capacity to tolerate and respond to disturbances. Diversity is recognized as a fundamental component of complexity, referring to species richness in ecological contexts and to the diversity of actors and their responses in socio-psychological contexts.

The analysis of resilience also varies according to the predictions and interventions that can be made to improve the functioning of social-ecological systems, involving both ecological and socio-psychological components. In this sense, resilience can be quantitively measured or qualitatively assessed in ecological, socio-psychological or social-ecological systems, through declining indicators specifically or generally according to the focus of the analysis. However, it is not possible to identify predominant models or tools to assess resilience. The process of assessing resilience begins with the delineation of what concept of resilience is being adopted, specifying also what kind of disturbances resilience refers to.

Consequently, a wide range of guides, frameworks, principles and assessment tools have been produced for ecological and social-ecological systems, enabling researchers to select the approaches more suited to the aim of their studies by directly investigating resilience, or its related factors. Some studies have examined the validity of these tools, leading to identification of weak results, since main features of resilience, such as diversity or agency, are often not adequately considered in quantitative analysis (Sanches et al., 2025). Furthermore, although the integration of disciplines would contribute to a more comprehensive understanding of resilience in complex systems, analysis of assessment instruments and methods have shown that disciplines still tend to be considered separately (Ruiz-Agudelo & Cortes-Gomez, 2026). In the light of this, resilience assessment methodologies must be further developed to increase their connection with the theoretical aims and key features of social-ecological resilience, stimulating approaches based on greater interdisciplinarity.

For the assessment of socio-psychological resilience in educational contexts, the tools identified usually quantify and qualify internal resources that enhance individual resilience, such as self-regulation, social skills, self-efficacy, learning capacities and knowledge. Nevertheless, the broader context is also evaluated, shifting the locus of change from the child to the resources provided by social-ecological environment. The resources and opportunities offered to the children by the educational environment, including family, community and society, must be incorporated within an ecological framework. The external influence of formal and informal educational environments strongly shapes socio-psychological resilience development in all aspects of the lives of children, with specific differences according to the cultural context. Therefore, cultural influences must be also acknowledged in the structuring of the tools to assess socio-psychological resilience, otherwise results will necessarily be altered.

From this complex multiplicity emerges a plural conception of resilience that is generally easier to qualitatively assess than to quantitatively measure, especially considering specific contexts, declining indicators on the basis of specific circumstances and challenges. At the same time, it must be recognised that the understanding of complex adaptive systems in terms of resilience will always be partial (Quinlan et al., 2016, p.683), involving qualitative assessment that can be enriched by further ongoing analysis to better understand the uniqueness of each situation.

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