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Vulnerability management by means of resilience

Kalliopi Sapountzaki

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Abstract The article decodes and analyzes the standard functions of social and social-ecological systems when they manage their own vulnerability. The author acknowledges these as "Resilience functions" or "Operational Resilience". For this purpose, she follows a "Vulnerability Actor" (V Actor)-based approach. V Actor is considered as a system faced with multiple hazards, carrying various vulnerability facets (physical, economic, institutional, etc.) and attempting to transform, transfer, rearrange them in time and space so as to achieve Actor's own persistence. It is these processes of vulnerability re-arrangement that are identified by the author as Resilience functions and which change the vulnerability not only of the V Actor performing resilience but also others'. Performance of Resilience functions presupposes attraction and employment of resources by the Actor, not only own, current and inherent but also other resources to be found in spatial and temporal scales external to or beyond the Actor but which the Actor can appeal to. This attraction most probably leads to deprivation of others of the necessary resources for their persistence, recovery, etc. When somebody' vulnerability is reduced sometimes somewhere, it is most probable that others elsewhere are encumbered with extra vulnerability, currently or in the future. Hence, what resilience can only do is vulnerability re-arrangement, re-setting and management. The proposed systemic approach is documented on current state of art regarding interactions between vulnerability and resilience to hazards and on empirical evidence from the international experience of responses to natural hazards.

Keywords Vulnerability to hazards · Resilience · Spatio-temporal change of vulnerability · Vulnerability management · Sustainability of socio-ecological systems · Multi-hazard vulnerability assessment

K. Sapountzaki (✉)
Harokopion University, Athens, Greece
e-mail: sapountzaki@hua.gr

1 Introduction: conceptions of theoretical and operational resilience and linkages with sustainability

Recently, the term resilience obtains growing significance not only among scientific fields such as Ecology and Sociology but in the context of the general language and daily life as well. The focus of the present work is on social and socially related systems (social-ecological, social-economic, social-institutional, etc.).

The use of resilience as a scientific term and concept has started from ecology wherefrom it expanded to social, behavioral and environmental sciences. Regardless of the scientific field and context wherein the term is found, resilience signifies reactions toward risks, shocks, stresses and adversities (with the ultimate aim of survival or persistence of the structure performing the attitude). In the scientific literature, resilience is defined basically in two ways:

- As an outcome expressed in relation to vulnerability and in particular as the flip side of vulnerability;
- As a process of self-organization and self-change in an attempt to retain essential functions or structure under circumstances of whatever stress or perturbation.

In the first case, i.e., when resilience is considered as the flipside of vulnerability, the two terms (and respective conditions) are perceived as opposite to each other: When a social system loses resilience, it becomes vulnerable (Kasperson and Kasperson 2001). According to such interpretation, mitigation actions decreasing the levels of vulnerability contribute directly to improving resilience of the system under consideration. In this sense, something is vulnerable to the extent that it is not resilient (see ENSURE project, Del 2.2. Galderisi et al. 2010). According to Cannon (2008, p. 10) "*high levels of vulnerability imply a low resilience and* vice versa".

This option of resilience as the opposite of vulnerability is found both in the Disasters' (e.g., Villagran De Leon 2006; Cannon 2008) and the Climate Change scientific literature. Representative of the first case is Villagran De Leon (2006, p. 50) definition of resilience as "*an intrinsic ability of a system, an element or a community to resist the impact of a natural or social event*". Representative of the second is the definition quoted in the IPCC Third Assessment Report (2001) "*a resilient system or population is not sensitive to climate variability and change and has the capacity to adapt*" (i.e., not vulnerable).

In "process"-related definitions, on the other hand, vulnerability and resilience are distinct concepts but linked with each other or mutually interacting. The relationships between these concepts are determined by the different views of the authors. Cutter et al. (2008) argue that there is not a clear and shared definition of the framework of relationships among vulnerability, resilience and adaptive capacity. In any case, the authors who put attention to the procedural aspect of resilience emphasize the role of learning capacity and of the decision processes in facing hazards. In this perspective, keywords for understanding resilience are re-organization and self-change (in the face of perturbation), which are achieved and managed with the help of learning capacity (or the ability to work-out external stimuli) and not only. Furthermore, it is not inevitable that above resilience processes lead to an outcome, which is the opposite of vulnerability (Linley and Joseph 2004; Paton 2008). The absence of vulnerability does not make one resilient (Manyena 2008). Vulnerability features may co-exist with characteristics that improve the adaptive capacity. "Process" inspired definitions of resilience are to be found basically with

reference to ecological, social and social-ecological systems (SES).[1] A representative of such definition is by Carpenter et al. (2001, p. 766) and later the Resilience Alliance who epitomized the basic features or determinants of resilience attitudes of SES:

> …(a) The amount of change the system can undergo…and still remain within the same state or domain of attraction, (b) the degree to which the system is capable of self-organization, (c) the degree to which the system can build the capacity to learn and adapt.

Bankoff et al. (2004) and Galderisi et al. (ENSURE project, Del 2.2, 2010) interrelate above definition of resilience of SES with the complexity theory. Indeed, the concept of self-organization (which initially referred to the property of systems to interact with external factors) is transferred to complex adaptive systems that have the potential to learn by experience, to process information and adapt accordingly. It is the relation of resilience to complexity theory that brings it very close to sustainability theories.

With respect to complex adaptive systems, the term self-organization refers to "*agents interacting locally according to their own principles or intentions in the absence of an overall blueprint of the system*" (Stacey et al. 2000). Adaptive systems do not just passively respond to events; they actively try to turn whatever happens to their advantage (Waldrop 1992). Such an interaction becomes source of further unpredictability and uncertainty.

After Wildavsky (1988) who acknowledges two ways of coping with uncertainty (anticipation and resilience), Dovers and Handmer (1992) adopt resilience as a useful concept for defining responses to ignorance, uncertainty and risk. Galderisi et al. (ENSURE project Del 2.2 2010) pinpoints that "pro-active Resilience"[2] as perceived by Handmer and Dovers (1996) is a notion akin to Conway's (1987) sustainability concept created for agricultural systems: "*the ability of a system to maintain productivity following large disturbance*".

The most important insights into resilience and sustainability in SES have been accomplished by Resilience Alliance in a report under the title "Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformation" (Folke et al. 2002). In this report, resilience and adaptive capacity are seen as the key properties for sustainability. Indeed, uncertainty and the struggle to cope with it permeate to debate on sustainability; the precautionary principle is a good evidence of the fact. This means that being resilient is a main objective of sustainability and sustainable development.

In the context of sustainable development, resilience is conceived as a process. The "Resilience and Sustainable Development" report (Folke et al. 2002) reads:

> Managing complex, co-evolving social-ecological systems for sustainability requires the ability to cope with, adapt to and shape change without losing options for future development. It requires resilience—the capacity to buffer perturbations, self-organize, learn and adapt. When massive transformation occurs resilient systems contain the experience and the diversity of options needed for renewal and redevelopment. Sustainable systems need to be resilient.

[1] Socio-ecological systems (SES) are basically identified as those composed of a societal (or human) component (subsystem) in interaction with ecological (or bio-physical) component (see Gallopin et al. 1989).

[2] Proactive Resilience is one which accepts the inevitability of change and tends toward the creation of a system that is capable of adapting to new conditions and imperatives (Handmer and Dovers 1996).

ISDR, in 2004, introduces the concept officially in the field of disasters, by defining resilience "*as the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure*". Besides Comfort's definitions and comments (1994, p. 114) regarding the role of self-organization (i.e., resilience) in the disaster management cycle:

> Disaster serves as a mechanism of transition of complex social systems that can either be used to redesign the system's structure and performance to fit more appropriately the vulnerabilities of its environment or, unattended creates the conditions for more serious or costly disruption at a later time…Self-organization is a spontaneous reallocation of energy and action in response to changes in the operating environment.

After embeddedness in sustainability research, resilience is transferred to the disaster field where it obtains a similar definition and the "process" oriented meaning. ISDR in 2004 introduces the concept officially in the field of disasters by defining resilience "*as the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure*". In this perspective of special interest is the earlier Comfort's definition (1994, p. 114) regarding the role of self-organization (i.e., resilience) in the disaster management cycle: "*…Self-organization is a spontaneous reallocation of energy and action in response to changes in the operating environment*".

Table 1 summarizes the distinct features and conceptual differences of the approaches of resilience.

The following section identifies open queries, which outline our knowledge gaps regarding operational resilience and address the contribution of the present work. The

Table 1 Basic features of the two theoretical approaches of resilience

Resilience definitions	Scientific fields involved	Systems of reference	Conceptual orientations
Resilience as an outcome or the "flip" side of vulnerability	Ecology	Engineering systems	Engineering Resilience
	The Disasters' field	Homogenous systems (e.g., ecosystems or social systems, etc.)	Equilibrium stability
	The Climate Change field		A stable condition
			Always positive
			Always predictable
Resilience as a process	Ecology	Integrated systems:	Ecological Resilience
	The Disasters' field	Social-ecological	Instability
	The fields of Sustainability & Sustainable Development	Social-institutional	Dynamic behavior
		Socioeconomic	Both positive and negative
			Unpredictable
			The means of coping with uncertainty and change
			A path to sustainability

Source Own elaboration

author having in mind the above-mentioned arguments and views attempts a step forward: to capture resilience in operation.

1.1 The contribution of the present paper: operational resilience

The findings of the two distinct approaches of resilience are acknowledged and adopted at least partly; this adoption, however, is under reservations and certain specifications and/or assumptions:

1. Indeed, resilience is connected with vulnerability in the sense that it has an ameliorating impact on vulnerability; however, this is true only for the system that employs the resilience attitude, other interconnected systems may experience increase in their vulnerability.
2. Indeed, resilience is a process of self-organization and change in an attempt of the system to persist, survive or retain essential structure under circumstances of hazard stress or perturbation. This process, however, is performed by systems behaving as "Vulnerability Actors" responding to a multi-hazard environment. It is suggested that this resilience process is a standard series of functions that are put in operation by "V Actors".
3. Resilience is determined by the material and intangible resources, those that the system is capable to employ; these resources and means, however, are not only the system's own and inherent but also external ones that are extracted from the social, economic and ecological environment at various spatial and temporal scales and for which other systems also might struggle.

Beyond confirmation of above assumptions and specifications, the author's hope and ambition is to reveal the "operational secrets" of resilience, i.e.,:

- What is the nature and character of the above called "Resilience functions"? What are the preconditions for these functions to be put in operation?
- What type and amount of resources does the system develop inherently and what does it attract from the close and distant environment to employ them consequently in the resilience process? When and in what way?
- How and how much Resilience functions performed by a particular system impact own and others' vulnerabilities?

The aim and scope of the present paper is to offer documentary evidence of the validity of the above assumptions and satisfactory answers to above queries, also "to take snapshots" of resilience in operation. To that end, the author adopts an "Actor at Risk" oriented approach, which has been adapted to the present work's rationale and perspective as follows: A "Vulnerability Actor" (V Actor) performs "Resilience functions" toward the end of own vulnerability reduction or improving own position.

2 The scope of action of a "Vulnerability Actor" (V Actor)

Actor-based risk and vulnerability approaches (constructivist approaches rooted in political economy) with distinctive milestone the book "At Risk: Natural hazards, people's vulnerability and disasters" by Blaikie et al. (1994) are to be found in both the Disasters' and Sustainable Development/Livelihoods fields. Indicative recent examples are the "Actor oriented approach to social vulnerability" by Boyle (2007) in the context of the Sustainable Livelihood framework, the study of the role of institutional actors (in risk management) in

the context of globalization by Christoplos (2003) and the most recent work by Klein (2007) focusing on international economic players profiteering in wars and disasters to the disadvantage of the victims and vulnerable social groups.

In the context of the present work Vulnerability Actor (V Actor) is considered, as a system capable to change own and/or others' vulnerability; for this purpose a V Actor employs Resilience. V Actor is "a vulnerability managing system" attempting to get rid of this undesirable property and influencing other actors' vulnerability (ENSURE project, Del 3.1, Sapountzaki et al. 2010). For instance, manufacturing firms resorting to dismissals in an effort to externalize recovery costs after a seismic disaster (the case of firms in Western Athens after the seismic event of 1999—see Sapountzaki 2005) are in essence V Actors managing to transfer part of their vulnerability to workers (i.e., other social agents). To refer to another example, the livestock farmers in the Prefecture of Ilia (in Peloponese, Greece) after the mega-fires of 2007 behaved as V Actors when they drove their flocks to areas with re-sprouting vegetation for grazing; in essence, these farmers attempted their own recovery by exploiting resources, which were vital for the recovery of the burnt forest ecosystem (Sapountzaki and Papachatzi 2010; ENSURE project, Del 2.1, Menoni et al. 2010). Indeed, a large part of the affected by the disaster livestock farmers vulnerable as they were (regarding prospects of survival) due to delays and inadequacies of consignments of provender drove their flocks to forest land under regeneration for grazing despite prohibitions and the strict penalties provided for law-breakers.

V Actors are actually "vulnerability carriers," which can obtain a kind of "consciousness" about their vulnerability because they are endowed with a potential to learn by experience, to process information and adapt accordingly, as is the case of complex adaptive systems (Bankoff et al. 2004). Hence, V Actors may be:

- Social agents ranging from the human individual and single household to communities (local, regional, national and global);
- Economic agents, such as firms, production sectors, regional economies, etc.;
- Institutional agents, e.g., fire departments, civil protection organizations, local authorities, central governments;
- Social-ecological systems (SES), such as an island community dependent on the island's hydrological system, etc.

Each V Actor is faced with several vulnerability facets[3] (ENSURE project, Del 3.1, Sapountzaki et al. 2010; Sapountzaki 2007). For instance, a local authority organization may be susceptible and responsive or not (i.e., vulnerable) to a series of losses and failures (e.g., loss of lives among the administration staff, damage of technical infrastructure and equipment, communication failures, operational and planning failures, loss of authority, etc.). Therefore, the organization carries and is faced with physical,[4] economic,[5] social,[6] institutional[7] vulnerability. Similarly, a firm may be faced with economic, social, physical, functional vulnerability. Vulnerability of an Actor is affected not only by this Actor's managing

[3] Vulnerability facets are the several versions of vulnerability, i.e., physical, social, economic, ecological, institutional, systemic.

[4] Propensity to physical damages and relevant (in)capacity to recover.

[5] Propensity to economic loss and relevant (in)capacity to recover.

[6] Propensity to social loss and relevant (in)capacity to recover.

[7] There are three versions of institutional vulnerability: (a) Inherent vulnerability of an institution relevant to the potential for direct physical damages and collapse of its components, (b) vulnerability of the institution's political/administrative role, i.e., probable incapacity to perform risk management policies and

capacities (resilience) but also by the respective initiatives of other Actors (due to systemic interconnections and finiteness of resources).

A V Actor may be active all along the disaster cycle or at specific stages only and targets simultaneously vulnerability to several potential threats arising from changes, not only natural hazards but also economic risks, social adversities, etc. (ENSURE project, Del 3.1, Sapountzaki et al. 2010). This is in line with theoretical suggestions that resilience is a key issue in coping with change in general. An empirical evidence of this attitude comes from the mitigation program promoted by an NGO and Red Cross in Caribbean islands. The program targeted physical vulnerability of residential buildings to hurricanes only, through incentives for structural reinforcement of the roofs (quoted in ENSURE project, Del 2.2, Galderisi et al. 2010). The program was largely opposed by the population on the grounds of an unshakeable argument (Cannon 2008, p. 6): "*Why spend money on a roof that will be proof against hurricane winds that may never happen, when each and everyday the household has to cope with an inconvenient and unhealthy kitchen?*" The example indicates that V Actors plan and act in an integrated manner by taking into account the real, holistic, multi-hazard context.

In case of wider geographical, socioeconomic or social-ecological systems, there are of course numerous V Actors, all struggling for own persistence, survival or recovery, i.e., for vulnerability minimization or improving own position. This is in line with Stacey et al. (2000), suggesting that self-organization, i.e., resilience, refers to agents following their own principles and satisfying their own intentions. It is also in line with Waldrop's suggestion (1992) that systems try to turn whatever happens to their own advantage. In this struggle, some of these Actors predominate and have determinant role in the formulation of the resulting vulnerability balance (ENSURE project, Del 3.1, Sapountzaki et al. 2010). In case of socio-ecological systems in particular, the social subsystems are usually the powerful ones jeopardizing the prospects of recovery of the ecological subsystems (unless the first apply strict institutional measures).

The V Actor utilizes own adaptive and resilience capacities to re-arrange and "reset" own vulnerability balance in time, space and among the several vulnerability facets (physical, social, economic, institutional, ecological, etc.) versus various hazards also, only when circumstances call for such re-arrangement (ENSURE project, Del 3.1, Sapountzaki et al. 2010).

In emergency and recovery periods after disasters, such efforts of vulnerability curing or re-arrangement are frequent and intense. Truly, it is in these periods that own vulnerability mitigation becomes a matter of survival and that abundant opportunities arise to capture and engage to own benefit brand new forms of capital.

In this perspective, the present paper suggests an operational definition of resilience: It is a system's capacity to (a) develop inherent resources and means usable to response and recovery, (b) extract additional means and resources from the social, economic and ecological environment and (c) engage/commit them consequently to own vulnerability reduction and/or improving own position. In this sense, resilience is a catalyst for vulnerability change, transfer and transformation but such processes may entail uneven distribution of exposures, response capacities and vulnerabilities in the social, economic,

Footnote 7 continued
(c) vulnerability of the linkages of the institution and its ability to coordinate with other co-responsible institutions.

political and geographical space. These inequalities result basically out of process of deprivation of certain weak V Actors of essential resources for their recovery or persistence to the benefit of the powerful V Actors. This is exactly what Cannon (2008) insinuates with his query (cited in ENSURE project, Del 2.2, Galderisi et al. 2010, p. 60): "*If some people in a community have a strong livelihood (and are wealthy) is this a resilience factor for them or a partial cause of the weaker livelihoods (and hence vulnerabilities) of others*?" Indeed, Cannon (2008 p. 10) elevated social inequalities in terms of resilience by arguing "*we need to acknowledge that within communities resilience varies according to opportunities that are distributed unequally*".

An instructive example of resilience inequalities is given by Klein (2007):

> Several months after the devastating 2004 tsunami foreign investors and international lenders, had teamed up to use the atmosphere of panic to hand the entire beautiful coastline over to entrepreneurs who quickly built large resorts, blocking hundreds of thousands of fishing people from rebuilding their villages near the water…Corporate goals are advanced by using moments of collective trauma to engage in radical social and economic engineering.

The above example shows clearly that resilience processes are performed not only by vulnerable victims but by external intruders as well.

As has been already suggested in the introduction of this paper, the V Actors perform the so-called resilience functions, which cause re-arrangement and change of their and others' vulnerability. The next chapter is dealing with this issue.

3 The resilience functions of a Vulnerability Actor aiming at vulnerability management

The V Actors in order to achieve their basic aim, i.e., vulnerability reduction and own persistence or improvement in own position, perform the so-called Resilience functions:

(a) Internal re-balancing of own vulnerability facets, meaning control and restriction of certain facets leaving others to deteriorate;
(b) Transformation and transfer of vulnerability (specific facets) to other V Actors;
(c) Re-distribution of vulnerability to the disaster cycle stages (current and future) and re-balancing between exposure and response/adaptive capacity;
(d) (Re)distribution between current and future hazards and
(e) Receiving vulnerability from other Actors.

Figure 1 offers a diagrammatic representation of the Resilience functions of a V Actor.

It should not escape attention the fact that an Actor's vulnerability refers always to the attached to or controlled by the Actor capital (human, social, economic, political, physical, etc.). Furthermore, it is this capital that is exposed and susceptible to losses, it is this capital that offers the resources needed for adaptive capacity of the V Actor and it is this capital that backs resilience (in addition to possible external resources that are abstracted from the social, economic and physical environment in pre- or post-disaster terms). Due to the finite character of resources at least in term of a disaster cycle and systemic interconnections between V Actors, vulnerability does not vanish; the resources that are spent for lowering a certain vulnerability facet will most probably result in an increase in another and those

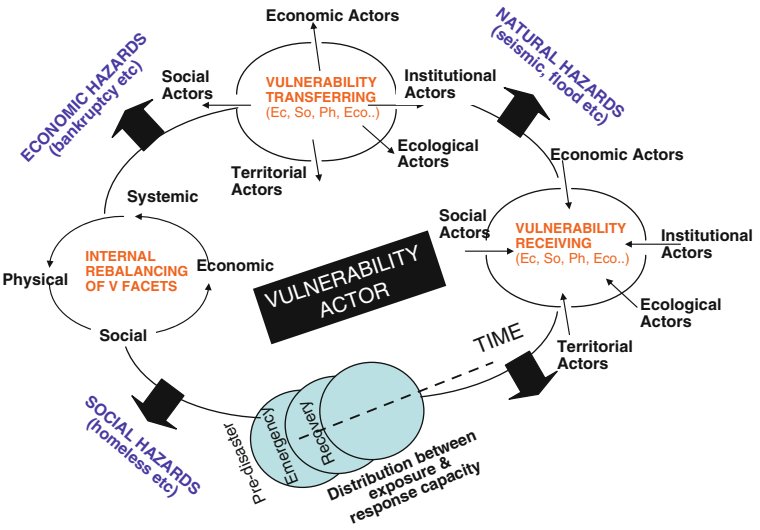

Fig. 1 The (resilience) functions of a Vulnerability Actor. *Source* Own elaboration

resources that are consumed on confrontation of one specific hazard will decrease available resources to ameliorate vulnerability to another hazard.

3.1 Examples of Resilience functions from the international experience

In the following paragraphs, specific case studies from the international experience are quoted as empirical validation of the Resilience functions suggested:

(a) During post-earthquake recovery of Small Manufacturing Firms in Western Athens (after Mt Parnitha earthquake 1999), most of them avoided public support for recovery and the "expensive" statutory procedures. Instead they favoured solutions externalizing recovery costs, such as extemporary self-repairs of manufacturing premises (Sapountzaki 2005). Actually, the entrepreneurs opted to keep their economic vulnerability low by increasing, however, physical vulnerability

Table 2 Internal re-balancing of V facets by SMFs in Western Athens (after the seismic event of 1999) by means of extemporary self-repairs of industrial premises

V Actor	V facet				
	Physical	Social	Economic	Institutional	Systemic
SMFs in Western Athens	+ (by means of extemporary self-repairs of damaged premises)		− (by avoiding expensive procedures to obtain a permit for building repairs)		

Source Own elaboration

\+ Increase in the specific V facet

− Decrease of the specific V facet

(see Table 2). The firms (and businessmen) performed that way an internal re-balancing of their own vulnerability facets.

(b) The case of devastating earthquakes of 2001 in Guzarat evidenced that lending money to affected communities or at least guaranteeing loans may be more effective than simply building physical structures. Reconstruction and rehabilitation turned to be a success because several local NGOs had ensured that affected villagers could access government compensation schemes and soft loans to help them rebuild their homes and lives themselves (IFRC 2004). It is obvious that people opted individualized rebalancing of vulnerability facets instead of unilateral curing of physical vulnerability.

(c) Davis (2005) in her exemplary case study of Mexico city after the earthquake devastating event of 1985 ("Reverberations—Mexico city's Earthquake and the Transformation of the Capital" in the book *The Resilient City* by Vale LJ and Campanella ThJ, eds) shows vividly how the authoritarian then political regime of Mexico transferred social vulnerability to the thousands of homeless citizens. By Davis's words (p. 269):

> The initial decision by authorities to use some of the earthquake reconstruction aid to repay Mexico's foreign debt…was seen as helping the country's financial institutions and elite at the expense of the thousands of mainly poor citizens who were left homeless.

The case illustrates that among the V Actors struggling for recovery and mitigation of own vulnerability are the political decision-makers, i.e., the governmental institutions themselves. In Mexico, the effort after the disaster has been toward survival and self-sustenance of the political system (by reducing its economic and institutional vulnerability) to the detriment of powerless victims and their recovery options. This is confirmed also by the flows of recovery funds (Davis 2005, p. 266):

> Even as it dragged its feet on housing, a much more concerted effort was made by the Government to rebuild or recover the major offices of the ruling party and the Government, many of which have been seriously damaged or destroyed (Table 3).

(d) In the same above case of Mexico's post-earthquake recovery and as has been evidenced by Davis (2005), it was not only authorities but citizens as well who could behave as V Actors and transfer Vulnerability to opposite direction, i.e., to the ruling party (in the long-term however). According to Davis's words (p. 274):

> …It may have been precisely the bull-headed resilience of the authoritarian PRI and its corrupt policing and administrative apparatus that led to the defeat of the ruling party in both the city and the nation several years later. That is, the eventual defeat of the PRI emerged in the context of the struggle between resilient citizens and this surprising resilient state.

(e) An obvious case of the function of *Vulnerability transfer*, one that involves socio-ecological systems, is the case of drought in certain Dodecanese islands (Greece), specifically Leros. In this specific Aegean island and under circumstances of acute water shortage, several consumers turn to unauthorized channels and networks of water procurement which operate in the island. These consist of drillers, possessors of water wagons, even local authority officials. By taking advantage of lay public's mistrust to official views, low standards of public services, lack of precautionary planning and lay public's preference to personal solutions, these networks that perform illegal water abstractions speculate on high demand for private water and

Table 3 Transfer of Vulnerability by the Mexico's Government and economic elite to the homeless after the seismic event of 1985

	To V Actor / From V Actor	**Homeless Households and mainly poor citizens who were left homeless**			
		INSTITUTIONAL V	**ECONOMIC V**	**SOCIAL V**	**PHYSICAL V**
Gover/tal authorities, ruling party, economic elite	**INSTITUTIONAL V**	—	— +	+	+
	ECONOMIC V	—			
	SOCIAL V				
	PHYSICAL V	—			

Source Own elaboration

\+ Increase of the specific V facet

− Decrease of the specific V facet

thrive (Sapountzaki and Wassehnoven 2005). Consequently, due to over-abstraction of water (a harmful resilience attitude), the quality and quantity of local water reserves deteriorates on a continuous base. Therefore, the hydrological system's vulnerability has been increased as well as vulnerability of the lawful water consumers and the wider social-ecological system of the island (see also ENSURE project, Del 3.1).

(f) The landslide of Venezuela (December 1999) demonstrated how the function of *redistribution of Vulnerability between current and future hazards* can be put in operation by political decisions. The landslide hit especially the Vargas state where alone 5,500 homes and apartments were wiped out, another 25,000 severely damaged and several roads, hospitals and water, sanitation and communication infrastructure were wrecked. After the disaster, the large-scale engineering works that were undertaken were impressive (8 months after the disaster 6 million of the 15 million tones of debris in Vargas had been removed, roads had been opened, river channels had been excavated and mountain dykes had been reinforced). The Government gave priority to technical infrastructure and works and underestimated social issues. Consequently, several months after the disaster, numerous families lived in houses with structural damage, many lacked potable water and adequate disposal of solid and human waste and in several cases three to eight people were sharing a room. Exposures and Vulnerabilities to new hazards had consequently been generated, i.e., exposure to future landslide and earthquake events, exposure to epidemics and problems of public health.

The examples quoted above clearly indicate that activation of Resilience functions depends largely on the availability and accessibility of:

(a) tangible (mostly economic) resources and assets, which are finite and lie basically at the hands of the wealthy, powerful institutions and the economic and political elite in general, both within and outside the exposed, victimized or vulnerable area/community;
(b) intangible resources (e.g., knowledge, experience, memory, political power, etc.) certain of which are possessed besides by the wider victimized population.

At this point, it is worth studying the resources that are usable in Resilience functions (both inherent and exogenous resources), also the preconditions of their engagement by the V Actor.

4 The resources usable to the development of Resilience functions

The international literature acknowledges as a critical dimension of resilience the so-called resourcefulness (see also ENSURE project, Del 2.2, Galderisi et al. 2010). This represents the capacity to mobilize and apply material and human resources to achieve goals during events of disruption (Bruneau et al. 2003). *Resourcefulness* is indeed confirmed by the theoretical hypotheses and empirical evidence of the present article as critical precondition of performance of the Resilience functions. The resources tapped in a Resilience process have been described as "capitals" of resilience: natural, financial, human, social and physical (Sapountzaki 2007). The same author emphasizes the importance of the spatial and temporal scales upon which the actor at risk appeals to mobilize and utilize needful resources. The larger these scales are the more affluent and diverse resources are to be found and engaged by the V Actor. In fact, *spatial and temporal scale appealing* and interactions have been addressed already as critical properties of resilience (see Folke et al. 2005 for socio-ecological systems and Chuvarajan et al. 2006 for social systems).

The case study of hydrological drought in Leros island, Greece, already mentioned above, is an instructive one about the resources that are tapped by V Actors, how these are attracted from various spatial and temporal scales and how these are treated to produce Resilience functions that re-arrange Vulnerability for the benefit of the V Actor. Leros is a small island in the East Aegean Sea, which belongs to the group of Northern Dodecanese. It is a territory of 53 km^2 with a permanent population of 8,207 inhabitants (Greek National Census 2001). The island is faced with water shortage, which in drought years turns to be water famine. The problem is a concern not only for the community of Leros but other Dodecanese islands as well and affects adversely all aspects of daily life and economic activity (Sapountzaki and Wassehnoven 2005).

The basic V Actors in relation to the water shortage problem in Leros and the resources employed by these Actors in an effort to cope with the problem are as follows:

- *The central Ministry of Agriculture* that supports the solution of dams and reservoir lakes to improve the supply side of the water balance: The Ministry, stimulated by the pressing necessity to absorb European Structural Funds and the pressures from contractors of public works, encumbers the local community of Leros with high (functional) costs of unnecessary and ineffective infrastructure. Consequently, the Ministry deprives the community and the local water supply company (DEYAL) of essential financial resources for really effective solutions.

- *The Dodecanese Prefecture* (established in Rhodes, the capital of the Prefecture) which grants licenses for always more and deeper drillings in an attempt to satisfy its "political clientele": It is evident that the Prefecture gains institutional and political benefits through deterioration of the hydrological system of Leros.
- *The local Municipal Services and Water Supply Company (DEYAL)* which attempt to decrease water demand and alleviate the vulnerability of the socio-hydrological system by enforcing stiffer pricing measures on lawful subscribers/water consumers: The latter suffer from deterioration of their social and economic vulnerability. At the same time, this policy mitigates DEYAL's own economic vulnerability.
- *The unauthorized drillers and water suppliers* who speculate on the problem of water shortage by turning to advantage relevant political tolerance and institutional weaknesses: These illegal drillers and water carriers (and their clients as well, those who manage to get cheap water and satisfy their own water needs) deteriorate hydrological vulnerability and improve their economic position by speculating on water demand. Besides they undermine institutional knowledge on the data of water cycle and quality and quantity of water reserves (institutional vulnerability), they deteriorate the quality of public water that is consumed by lawful users and raise the payment share of the latter for access to public water (social and economic vulnerability).
- *Lawful consumers* (among them hotel keepers, permanent residents and farmers) who are faced with constant increase in their own vulnerability: This is because the problem of water deficiency is not resolved and many private and mostly illegal V Actors satisfy their water needs by depriving others and discrediting public institutions.

Table 4 below indicates the resources utilized by each one of the V Actors in their attempt to get rid of their own vulnerability (and exposure) or benefit from the water shortage problem of Leros. One learns from the table that some of the V Actors manage to tap resources of the future (such as fossil water) and to appeal to supra-national spaces (economic, geographical and political). Also, that some of the V Actors manage accessibility to a bundle of resources (close and distant), while others are obliged to utilize only the limited inherent or endogenous. It is evident that the networks of illegal water supply are the most active Actors managing to appeal to powerful posts and markets and to combine successfully (for own profit) institutional resources (such as tolerance of illegality) but also social, technological and economic resources.

The analyzed example but also other cases of disaster cycles and especially emergency and recovery phases are all featured by the same restless condition: a continuous struggle and competition for resources. Whoever manages to engage and employ larger than other part of the available post-event capital, this Actor then achieves higher rates of resilience development and vulnerability decrease. On the contrary, those Actors who are deprived of the prerequisite for response and recovery means and resources may find themselves in a worse-off position at the end of the recovery phase (i.e., probably non-recovered and faced with new vulnerabilities to secondary hazards, etc.). Their only possibility is the development of own inherent and mostly intangible resources (e.g., inventiveness, support from family members, etc.).

It appears consequently that social and socio-ecological systems acting as V Actors after having been hit by a hazard develop resilience, which depends on the available/accessible by the system forms of pre-disaster capital (after losses) and post-disaster extraordinary forms of capital that are latent or non-existent in normal periods. It has been already clarified that above resilience resources are not only the inherent of the V Actor. Other

Table 4 Resources employed by the basic "Vulnerability Actors" in the island of Leros for the purpose of coping with the water shortage problem

V Actors	Resources						
	Natural capital	Economic capital	Social-human capital	Political/instit. capital	Physical capital	Spatial scales/levels APPEALED TO BY THE ACTOR	Temporal scales/range of tapped resources
Ministry of Agriculture		**X** (European Structural Funds)			**X** (Dams and reservoir lakes)	European level National level	Long-term solutions
Prefecture — Department of Land Reclamation Works	**X** (Always deeper drillings)					The whole island's territory and beyond	Abstraction of fossil water
Water Supply Company of Leros (DEYAL)—Municipal Council		**X** (extra financial resources coming from increased water rates)		**X** (Political power to impose strict pricing policies)		The population of the lawful subscribers/ consumers of Leros	
Networks of illegal water supply and their clients	**X** (Always deeper drillings)	**X** (Investment in drilling technological equipment)	**X** (Preference of personal ways of solving one's own problem; trust in own intuitive knowledge)	**X** (Institutional gaps: tolerance of illegality, lobbying, etc.)		Accessibility to economic and political posts and resources at local, regional even national level	Abstraction of water of the future
Lawful consumers connected to the public network of water supply, managed by DEYAL		**X** (payments of always higher water rates)	**X** (Trust in public institutions, collective solutions, official views)				(Traditional inherited knowledge about devices, methods and practices for water saving)

Source Own elaboration

X Usage of the specific type of capital by the specific V Actor for the purpose of development of a Resilience function

resources are included also those that might be extracted from spaces external to and beyond the Actor (geographical, social, economic, etc.) which, however, the Actor can have access to.

As regards exceptional post-disaster resources usable to resilience, these may be either private or resources under social control. Examples in the first category are behavioral assets, personal knowledge, memory and experience, private property assets, etc. Resources under social control are social knowledge, extra institutional mechanisms and parallel structures of illegality due to temporary collapse of the system of formal rules and prohibitions, new forms of demand and job opportunities, networks of social trust and solidarity, public offers and private donations, external aid, etc. (see Sapountzaki 2007).

Accessibility to resources and the ability of a V Actor to block and bind them for the development of Actor's own Resilience functions is measured by parameters that are already familiar to the researchers of the field. Beyond the parameters that have been mentioned already, i.e., resourcefulness, networking, spatial and temporal scale interactions, other parameters that might be used also as measures of the Actor's ability to capture resilience resources are diversity, learning capacity and redundancy (i.e., existence and availability of substitutable elements).

5 Epilogue: a new opportunity for a coupled approach/assessment of resilience and vulnerability dynamics

Collection of resources by a V Actor is not enough for the development and operation of Resilience functions. The V Actor has to organize further these resources so as to feed an operational process transforming and generally changing Actor's vulnerability. Besides, it is important that the V Actor has "a broad perspective" of the whole range of hazards threatening Actor's existence, primary and secondary hazards, current and future (and relevant vulnerabilities) and is capable to prioritize options of vulnerability reduction. These abilities of V Actors to transform collected resources into vulnerability re-setting operations have been addressed in the international literature eloquently with such terms as: "creativity", "adaptability", "self-organization", "innovation", "learning capacity", "transformability", "self-reliance", "feedback", "flexibility" , etc. (see also ENSURE project, Del 2.2, Galderisi et al. 2010).

The approach of "V Actors performing standard Resilience functions" allows for the development of a methodology to assess the impact of a V Actor's Resilience functions on Actor's own and others' Vulnerability. The steps of this methodology are presented in Fig. 2.

It has already been mentioned that V Actors are not only those located in the exposed or hit territory but also Actors located outside or (in case of authorities) higher-level Actors commanding wider jurisdiction areas, which are seemingly out of the range of the threat. Indeed, resilience and vulnerability levels of the exposed or victimized Actors is the composite outcome of various multi-level decisions and interactions extending beyond the exposed territories and involving non-exposed Actors too.

In cases where the object of interest is not a single V Actor but a whole community or socio-ecological system with a crowd of V Actors, the application of above methodology is possible only through a deductive approach. The researcher has to elevate the predominant Actors in the response and recovery phases and study consequently vulnerability transferences among them and re-allocations of V facets and to multiple hazards too, to finally estimate Vulnerability increases and decreases at an advanced stage of the

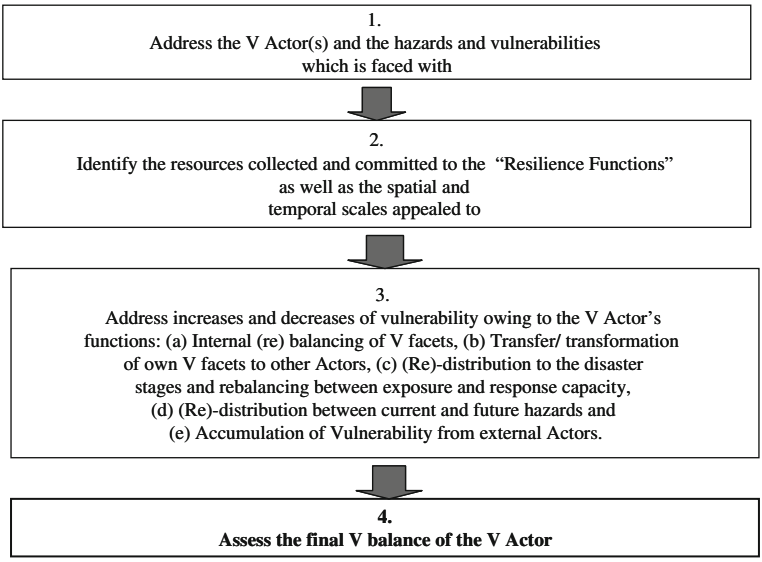

Fig. 2 The steps of a methodology to address the impact of "Resilience functions" on vulnerability. *Source* Adjusted from ENSURE project, Del 3.1, Sapountzaki et al. (2010)

recovery–rehabilitation phase. In a Vulnerability assessment study, what actually matters is vulnerability change because vulnerability is a dynamic and relational property.

The resources that are attracted and consumed on the development of Resilience functions and the ultimate aim of vulnerability change constitute a realistic measure of the change of vulnerability that has been achieved. Future vulnerability changes of an Actor can be anticipated on the basis of statistical data and scenarios about the Resilience functions that the V Actor can develop. Interviews and questionnaires addressed to V Actors might prove helpful to this direction.

The ENSURE project (Del 3.1, Sapountzaki et al. 2010) offers designative examples of application of the above methodology. Worth referring to are the cases of: (1) Flooding and chemical spillage following hurricane Katrina in St Bernard Parish, New Orleans, USA, August 2005; (2) the socio-ecological system of Northern Negev (Israel) facing agricultural drought.

In the first case, the predominant V Actors addressed were:

- The local population of St Bernard Parish;
- The multi-national Murphy Oil Company;
- The Federal Government through FEMA, the US Army Corps of Engineers and the State Emergency Response Organizations;
- Insurance companies;
- NGOs;
- Neighboring communities and States and
- Other Regions in which Murphy operates.

Regarding the resources collected by above V Actors, interesting and prominent is the case of the Murphy Oil Company, which exhibited high resourcefulness and capability to appeal to various spatial scales and governmental/administration levels:

- The company appealed to the US Environmental Protection Agency (EPA) and the US Coast Guard (regional level) for dealing with the oil spillage;
- As a multi-national company, it appealed to shareholders and affiliated companies for financial resources (global scale);
- It took advantage of government tax-bonds after Katrina to support own repairs and reconstruction (national level).

Regarding transferences, redistribution and accumulation of vulnerability, these have proved indeed to cover extensive spatial and temporal scales and institutional ladders in line with the theoretical suggestions of this paper. Eloquent is the case of those home-owners and business people of St Bernard Parish whose properties had been contaminated and who managed (through legal action) to receive financial compensations by the Murphy Oil Company. Consequently, they transferred part of their costs and vulnerability to the company's shareholders globally.

In the second case of Northern Negev (Israel) facing agricultural drought, the pre-dominant V Actors addressed were:

- The Jewish farmers in Northern Negev;
- The Bedouin farmers;
- The Ministry of Agriculture in Tel Aviv;
- The Ministry of Finance;
- Mekorot, the state owned company responsible for water supply to agriculture.

This case is interesting in that it demonstrates vulnerability transferences in between the basic V Actors exposed to drought, where these transferences originated actually from a third, non-exposed V Actor located far away from the exposed area. Indeed, the Ministries of Agriculture and Finance bear the responsibility of demarcating and declaring areas prone to drought wherein farmers receive compensation during the drought years. By this action, the Ministries mitigate social and economic vulnerability of certain areas and communities (inside the drought border lines) and transfer vulnerability to those outside.

The basic lesson learned out of this paper is that vulnerability reduction in a social agent or community or socio-ecological system can only be partial, unilateral and temporary. When somebody's vulnerability is reduced sometimes somewhere, it is most probable that others elsewhere are encumbered with the same or other forms of vulnerability currently or in the future.

Vulnerability does not vanish at least in short and medium terms because it is the lack and limited character of resources (financial, technological, human, natural, physical, social, etc.) that produce vulnerability. Therefore, vulnerability can be faced only by sponging on others, other places and other times but cannot be eradicated altogether. What resilience can only do is vulnerability re-arrangement, re-setting and management. It might cure certain aspects of vulnerability by triggering the emergence or increase in other aspects, of other Actors, to other hazards, now or in the future. It is for this reason that resilience and its fight against vulnerability can never be studied with a view of one specific hazard. Resilience lies at the root of our unstable, temporary existence in a multi-hazard context.

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