ensure	**ENSURE PROJECT** *Contract n° 212045*

WP 3: Vulnerabilities in Time and Space

Del. 3.1:
Analysis of vulnerability factors versus time

Reference code: ENSURE – Del. 3.1

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List of Abbreviations

AFAK	Australian Fire and Emergency Service Authorities Council
CoS	Council of State
DASK	Turkish Abbreviation
DEYAL	Local Water Supply and Sewerage Company
DoW	Description of Work
DV	Depth of Vulnerability
DVR	Recovery capacity and depth of Vulnerability
ECOL	East Mediterranean Centre for Oceanography and Limnology
FEMA	Federal Emergency Management Agency
FEMA	Federal Emergency Management Agency
GCMs	General Circulation Models
GCMs	General Circulation Models
IEMP	Earthquake Master Plan for Istanbul
IMM	Istanbul Metropolitan Municipality
ISMEP	Istanbul Emergency Preparedness Project
JICA	Japan International Cooperation Agency
NDVI	Normalized Difference Vegetation Index
NGOs	Non- Governmental Organizations
NUTS	Nomenclature of Territorial Units for Statistics
PASOK	Panhellenic Socialist Movement (Greece)
R	Capacity to Recover
TCIP	Turkish Catastrophe Insurance Pool
TUBITAK	Scientific and Technological Research Council (Turkey)
USACE	US Army Corps of Engineers
WWF	World Wide Fund for Nature
YPECHODE	Ministry for the Environment, Spatial Planning and Public Works (Greece)
YPEKA	Ministry for the Environment, Energy and Climate Change (Greece)

1. Executive Summary

The present Deliverable 3.1 focuses on variability and evolution of vulnerability over time. Two temporal scales have been considered relevant:

- A single disaster cycle and its successive stages;
- A series of successive disaster cycles or events;

Since vulnerability changes over time depend on the respective changes of its constituent components and of other catalytic factors influencing vulnerability, the present Report is simultaneously a study of variability and temporal changes of such properties as Response / Coping Capacity, Resilience, Exposure, Susceptibility Loss.

In order to achieve the Report's objectives, the authors employed the already familiar terms, concepts and methodologies from previous WPs 1 and 2, in particular, the "Vulnerability Facets" approach and the akin terms Vulnerability to Stress, Vulnerability to Loss, Exposure, Resilience, Response and Coping Capacity. Besides, they introduced new ones, in particular the "Vulnerability Actor or Agency" approach and the terms "Vulnerability Actor", "Vulnerability Transfer and Transformation", "(Re)balancing", "(Re)distribution", "Receiving" (to test their validity too by means of case studies). In parallel, both the theoretical background (Chapter 3) and the case studies that follow (Chapters 4,5,6) involve in the discussion about vulnerability dynamics pre- and post-disaster capital in its several forms (human, social, economic, physical, natural, political), i.e. the resources engaged in response and coping capacity building.

In the conclusions and taken for granted the dynamic and variable nature of vulnerability the authors wonder whether the proper research query of ENSURE project and also in any case of a vulnerability study, should not refer to how to assess composite vulnerability levels (as if these remain constant) but how to identify the forms and carriers of vulnerability being on the increase.

Partial issues and queries dealt with in the present Report are the following:

- ✓ How do certain vulnerability facets generate others along the stages of a single event or a series of events;
- ✓ How do specific vulnerability facets change from pre-disaster to emergency and recovery periods and what are the basic "vulnerability phases";
- ✓ How do specific vulnerability facets change from a disaster event to the next one, to the third event and so on and what are the basic catalytic factors;
- ✓ How do response/coping capacities modify vulnerabilities and what is the role of such processes as vulnerability transferring, transformation, receiving, rebalancing etc;
- ✓ Who/which systems/agencies do mitigate and who/which deteriorate their vulnerability at the end of a disaster cycle or after a succession of disaster events, also which facets of vulnerability do increase and which decrease and why;
- ✓ What is the role of resilience (and other catalytic factors) in the above processes of vulnerability increase/decrease;

Chapter 3 under the title "General Concepts and Objectives" offers theoretical explanations and guidelines for the case studies that follow (Chapters 4, 5, 6), the authors of which might opt one of the two (or both) alternative approaches provided, i.e. the "Vulnerability Facets" and the "Vulnerability Actor" approach.

Chapter 4 under the title "Patterns of Vulnerability Evolution from the Pre-disaster to the Recovery Phase" hosts case studies focusing on one or more of the several facets of vulnerability (physical, social, economic, institutional, techno-systemic, territorial, eco-systemic) and their fluctuations over the stages of a single disaster cycle. The case studies included are:

- The case of Vesuvius volcanic eruptions illustrating vulnerability changes owing to hazard transformations;
- The case of economic vulnerability of the local population of St Bernard Parish affected by flooding and subsequent chemical spillage in the Hurricane Katrina disaster, 2005 (a Na-tech case);
- The case of wildfires in Australia illustrating the evolutionary course of ecological, physical and social vulnerability;
- The case of vulnerability sequences in St Bernard Parish and the Katrina flood and oil contamination events of 2005.

Chapter 5 under the title "Patterns of Vulnerability Evolution over Successive Disaster Cycles" hosts case studies focusing on one or more of the several facets of vulnerability and relevant changes occurring from one event to each next that follows:

- The case of accumulated impact on vulnerability out of successive earthquake events: The El Salvador 2001 crises;
- The case of accumulated impact on vulnerability out of successive hydro-meteorological and earthquake events: The French West Indies 2004 crises;
- The case of forest fires in the Mediterranean Region: Accumulation of ecological vulnerability and changes in resilience;
- Vulnerability changes after the Friuli earthquakes of 1976;
- Evolution of institutional vulnerability to earthquakes: Legal framework changes after earthquake events in Turkey;

Chapter 6 under the title "Vulnerability Actors Steering Vulnerability Changes along the Successive Stages of a Single and/or Successive Disaster Cycles" hosts the case studies that have followed the "Vulnerability Actor" approach. In particular the case studies included in the Chapter are:

- The case of Acheloos river diversion as a response to the agricultural drought of Thessaly (Greece) and the multi-level actors involved;
- The case of micro-scale vulnerability actors involved in the flooding and chemical spillage in St Bernard Parish, New Orleans (USA) after hurricane Katrina, 2005;
- The case of the eco-human system of Leros, Dodecanese islands (Greece) and the actors managing its hydrological drought problem;
- The case of the eco-human system of Northern Negev (Israel) and the actors managing its agricultural drought problem;
- Mechanisms of vulnerability transference in the Abruzzo earthquake case.

Chapter 7 summarizes the conclusions of the Report, as regards especially methodologies of arresting fluctuations of vulnerability, resilience, response/coping capacity, exposure and of their interactions in the course of time. It seems that the response / coping capacity of the vulnerable systems under examination and the forms and quantities of capital committed in this capacity building (with the help of resilience) are crucial because these factors determine winners and losers out of the vulnerability fluctuations.

2. Introduction

According to the DoW the central theme of the present Del 3.1 is identification / assessment of vulnerability changes and the respectively determinant factors in the course of time (in terms of disaster phases and the historic development of vulnerability). The temporal scale of a single disaster cycle (from prevention to reconstruction) has been considered as representing short term changes and transformations while the temporal scale of a series of successive disaster events (either akin or dissimilar from each other) has been considered as appropriate for coverage of long-term transformations and trends of increase/decrease (figure 1).

It is evident that the Deliverable is pre-occupied with the dynamic, unstable nature of vulnerability. If we are talking about vulnerability to stress this variability originates from (among others) hazard changes and transformations (indicative is the case of volcanic eruptions); if we are concerned with vulnerability to loss its variability is connected among others with the transmutation of losses (from one stage to the next or from one event to another). However, fluctuations of vulnerability do not come predominantly from such external factors as is hazard.

Vulnerability may be modified during periods of dormancy of hazards or when losses are being cured and recovered. Indeed vulnerability changes also because of the fluidity of its internal components, predominantly of response and coping capacity. In other words it is the ability of the systems to manage vulnerability that determines vulnerability levels at any specific moment.

Therefore the study of vulnerability evolution over time is simultaneously a study of variability of all determinant factors, i.e. the hazards, exposure, response/coping capacity, resilience and susceptibility to loss.

Chapter 3 below establishes a theoretical background and guidelines for case study elaboration to meet the objectives of the Deliverable, introduces and defines new terms and concepts and offers to the authors of the case studies two alternative methodological approaches.

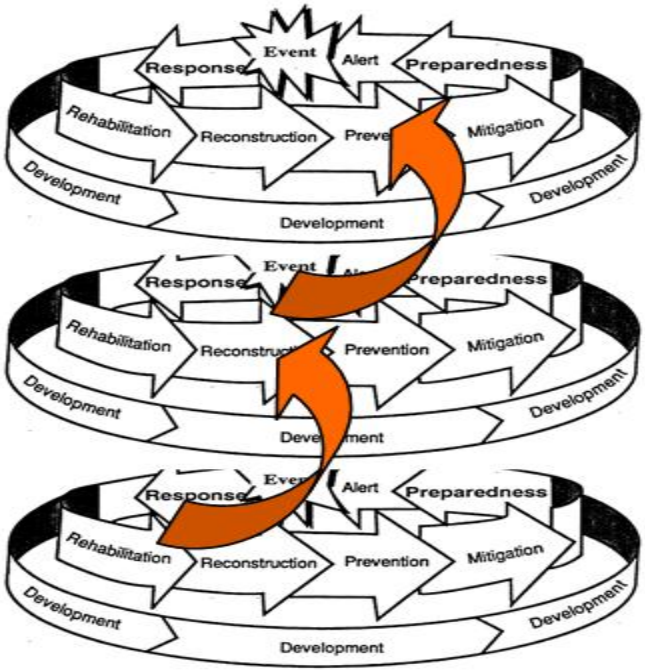


Figure 1: The temporal scales of consideration

3. General Concepts and Objectives

The main focus of WP3 is vulnerability fluctuations, differentiations, transferences, transformations and in general vulnerability changes in time and space. According to the Dow the objectives of WP3 are:

- To address multiple facets of vulnerability that are determined by (a) the type of hazard under examination, (b) the type of the agency / structure carrying vulnerability, (c) the period of concern, (d) the type of losses / damages of reference, (e) the geographical position / range / scale of both the potential disaster event and the agency / structure affected.
- To address linkages and interdependencies between the above distinct types of vulnerability.

Among the key terms being referred to in the above objectives some emerge for the first time and their meaning and content has to be fully explained. These are: (1) the type of the agency / structure carrying vulnerability, (2) the period of concern (for considering vulnerability changes) and (3) the geographical position / range / scale of both, the potential disaster event and the agency / structure affected. The periods of concern have already been defined in the Introduction. The other terms are explained and further analyzed in the following paragraphs.

3.1 The "Vulnerability Actor" or the "Agency / System Carrying Vulnerability"

Several case studies included in WP2 (see T.2.1 and T.2.2, also D.2.2) have indicated that vulnerability is transferred, transformed and/or rebalanced at least by the competent for risk mitigation institutions. This capability of institutions to transfer, re-allocate, redistribute vulnerability in time and space is so evident that allowed the authors of T.2.1 to aptly define Institutional Vulnerability as "the exposure and vulnerability of individuals, communities or organizations to the uncontrollable adverse consequences of another organization's critical shortcomings". But institutions are not the only "Vulnerability managers" or "Vulnerability Actors". For instance, manufacturing firms resorting to dismissals in an effort to externalize recovery costs after a disaster are in essence Vulnerability Actors managing to transfer part of their vulnerability to labourers (i.e. other social agents). Similarly, Vulnerability Actors were the livestock farmers, after the mega-fires of 2007 in Peloponnese, Greece; these economic/social actors attempted their own recovery by abstracting/engaging for themselves resources (such as land and re-sprouting vegetation) which were vital for the recovery of the stricken by the fires forest ecosystems too. Indeed 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 relevant prohibition and the strict penalties provided to be imposed to law-breakers.

The above vulnerability carriers function indeed as "Actors" conscious of their vulnerability, willing to get rid of this undesirable property and being capable of relevant responsive action. Vulnerability Actors are in essence entities capable to change their and others' vulnerability; for this purpose they employ their adaptive, coping and/or response capacity. These Vulnerability Actors may be *social actors,* ranging in scale from that of the human individual (or the single household) to the national and global communities'; *economic actors,* ranging between the single firm and national economies or the global one; institutional actors (e.g. individual fire or police departments, wider emergency mechanisms at the regional level, a whole political / administrative system at the national level etc). The above actors, irrespectively if they are micro-, medium or macro-scale actors are capable of

altering, i.e. managing, to some degree (some to a high others to a low degree), the vulnerability of the controllable or accessible by them forms and quantities of capital (human, physical, social, natural, economic capital). Hence Vulnerability Actors are virtually managers of the vulnerability of a system and facing multiple facets of vulnerability. For instance, a local governance system is susceptible to and may be responsive to a series of losses and failures (loss of lives among the administrative staff, loss of administrative buildings and equipment, communication failures, operation executing failures, planning failures etc). The same holds true for a household even for an individual person.

We are naturally aware that social, economic and institutional actors cannot be treated as if they have the same character and properties. Individuals, households and firms are victims of a disaster in a different sense than institutions (e.g. units of local government, government departments etc.) Therefore the ways they manage their vulnerability and then transfer or rebalance it must be differentiated. This is a point that must be kept in mind in other sections as well (e.g. 3.4.2).

Under the above perspective all accessible or controllable forms of capital by a Vulnerability Actor are simple adjuncts of this Actor or they formulate together a "Vulnerability managing system". Indeed a household exerts some sort of influence over and/or regulates to some degree the vulnerability of its "possessions" and all inevitable linkages with the ecological, social, economic, physical and institutional environment (e.g. vulnerability of family members, own house and interactions with the surroundings, household appliances' kinship and friendship networks etc). Simultaneously, each (systemic) Actor and his/her/its vulnerability is affected by the vulnerability managing capacities of other actors.

In the case of wider Territorial and Eco-human systems there are of course numerous Vulnerability Actors, all struggling for own survival and recovery, i.e. for vulnerability minimization. Some of these Actors predominate and have determinant role in the formulation of the resulting vulnerability balance.

The "Vulnerability Actor" utilizes his/her/its coping, adaptive or response capacity to rearrange and "reset" own vulnerability balance in time, space and among the several vulnerability facets (to various hazards also) only when circumstances call for such re-arrangement. During emergency and recovery periods such efforts of vulnerability curing or re-arrangement are frequent and intense, not only because it is then that own vulnerability mitigation becomes a matter of survival but also because in such periods emerge opportunities for capturing and engaging to own benefit brand new forms of capital for this purpose. Consequently, geographical range and position of the systems functioning as Vulnerability Actors is important not only because these properties determine the degree of exposure of the Actor and hence potential losses and internal vulnerability but also because these properties affect the prospects of the Actor to grasp post-disaster opportunities and capital and boost own response capacity.

Needless to say that we do not wish to imply that vulnerability is a matter concerning exclusively the post-disaster period, given that it is primarily a pre-existing condition. We simply mean that further forms of vulnerability develop during the emergency / relief/ reconstruction period. A similar point can be made with regard to section 3.2.

3.2 Vulnerability changes along the successive stages of a single disaster cycle

Vulnerability undergoes significant transformations from the pre-disaster (prevention / preparedness) period to the emergency and afterwards to the recovery / reconstruction period.

At first vulnerability is manifested by means of "waves of losses" as several case studies in WP2 connote. More often than not, first order losses are physical and ecological losses owing to vulnerability to stress. These depend on the characteristics of the stress and occur only when these characteristics surpass specific thresholds. These first order losses trigger off first order social and economic losses, eco-systemic, techno-systemic and institutional losses. First order losses are followed by second order ones, physical and ecological, eco-systemic, techno-systemic and institutional, social and economic, third order ones etc. Each order of losses either on its own or coupled with other orders of the same or different loss categories may produce sequential orders of losses. For instance, loss of jobs may occur again and again (at intervals) after a disaster event as a result of other successive and combined losses and failures, increasing thus gradually the overall unemployment rate out of a disaster (see T.2.2, section 6.b).

Except first order physical and ecological losses owing to vulnerability to stress all the rest are basically attributable to vulnerability to loss. In such cases it is the characteristics and extent of the antecedent, causal losses (and relevant thresholds) that determine the resulting types and intensity of losses of subsequent order. Of course, the above continuous and expanding in time and space loss production process (reaching its peak at a certain moment of the disaster cycle) is much more complex when hazards shift from individual phenomena towards "an interactive mix of natural, technological and social events" or to the so called coupled events (natural-natural, natural-technological, technological-technological) (see D.2.2, section 3.1).

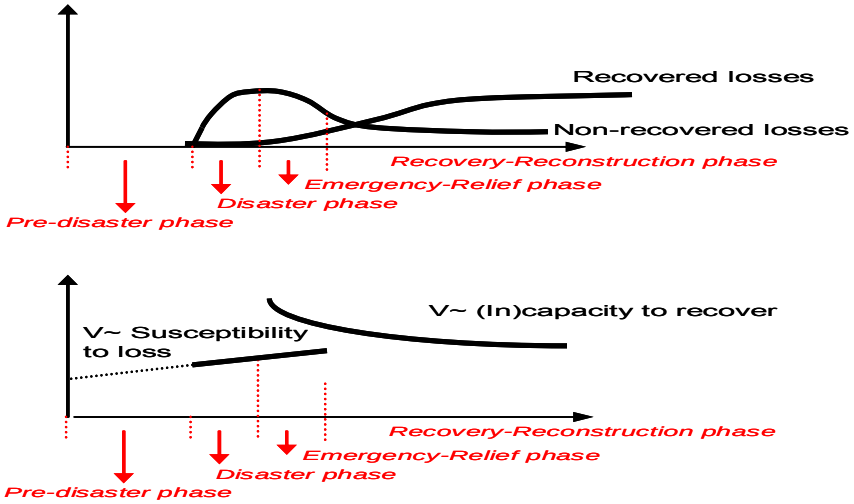


Figure 2: An indicative representation of the changes of vulnerability manifestation through the phases of a single disaster cycle – The role of "capacity to recover"

Viewing vulnerability manifestation through the lens of the distinct phases of the disaster cycle and by taking into account the definition of Vulnerability as "vulnerability to stress and the capacity to recover", one can distinguish accordingly:

(a) *From prevention to the disaster phase,* where vulnerability is manifested almost exclusively as "susceptibility to loss".

(b) *Emergency and relief phase,* where vulnerability is manifested as both "susceptibility to loss" and the "incapacity to recover".

(c) *Recovery-reconstruction phase,* where vulnerability is manifested almost exclusively as the "incapacity to recover" (see following figure 2)

It ensues from the above that vulnerability in the pre-disaster and disaster phase (up to the emergency phase) is largely affected by exposure (both to stress and to potential or actual losses). However, exposure here is meant in the widest possible sense, i.e. as a function not

only of location in the geographical space but also of position in the social, economic, political, psychological and technological hierarchy (always in connection to the hazard). On the other hand vulnerability in the emergency-relief phase is affected by both susceptibility to loss (and hence exposure) and response capacity while in the recovery-reconstruction phase vulnerability is fundamentally a matter of response capacity (and hence the resources which are essential for recovery in the form of physical, natural, social, economic, cultural capital). This should not make us forget that the preconditions for a high or low response capacity are formulated (to a large degree) by processes that take place during normal periods.

The above consideration refers of course to the vulnerability to the initial hazardous event. Should a second hazard (as an independent event or triggered off by the first hazard) appear in the scene soon after the first several facets of vulnerability and to multiple hazards will simultaneously emerge. It follows from the definitions adopted in WP2 (see T.2.3) that the course of each one of the vulnerability facets (physical, ecological, systemic, social, economic, institutional, territorial) through the stages of the disaster event is determined by the respective evolution tracks of susceptibility to loss on the one hand and capacity to recover on the other. Section 3.4 presents and analyzes two alternative methodological paths for monitoring above vulnerability courses.

3.3 Vulnerability evolution through successive disaster cycles

The cases illustrated in sections 6.b and 7.d of T.2.2 (and not only these) evidenced in an eloquent way that some systems manage to have decreased their overall vulnerability (by their response capacity) once the disaster cycle has been completed; however, other systems may find themselves in a worse off vulnerability position when they reach the end of this cycle. This means that these disadvantaged systems enter a new disaster cycle from a deteriorated starting point in comparison to that of the previous disaster event. As long as this process of deterioration keeps on the systems will suffer more and more losses after each subsequent catastrophic event; or in other words the thresholds of hazard features which provoke losses when surpassed will become lower and lower after each subsequent event.

Reference to the dynamic effects of vulnerability which is left in the aftermath of one disaster on the next disaster in the same place (and hence to the issue of vulnerability evolution through a series of events) is also made in Del.2.1.1 (section 5.4). In particular, the relevant extract reads (p. 68):

> *"It is clear that one disaster and the condition in which it leaves an exposed population after reconstruction and recovery may lead to a level of vulnerability which may either reduce or increase the effects of the next disaster. This dynamic contains within it feedbacks and cycles of influence-feedback-influence"*

Besides, authors of T.2.1 have elaborated a figure (Fig. 3) to depict in a simplified form an integrated conceptualization of how economic and social vulnerability are related through "influence-feedback-influence cycles" which take place continually over time. The portrayal is actually a snapshot of a fairly lengthy period (50 or70 years). It is evident from the figure (that it covers a period of two successive disaster cycles) that institutional vulnerability makes inputs over time. As authors (T.2.1, p.74) suggest:

> *"In this example institutions are incapable of holding back a steady increase in physical vulnerability over time, especially exposure of more and more people and assets to hazards….but in another case physical vulnerability might be declining over time, perhaps as institutions become more effective by introducing counter-vulnerability policies"* .

Indeed the objective here is understanding, analyzing, assessing and representing evolution of the several facets of vulnerability over a long period the milestones of which are the manifested within disaster events; additional objective is correlation between evolution lines of the several vulnerability facets and the respectively determinant factors / parameters.

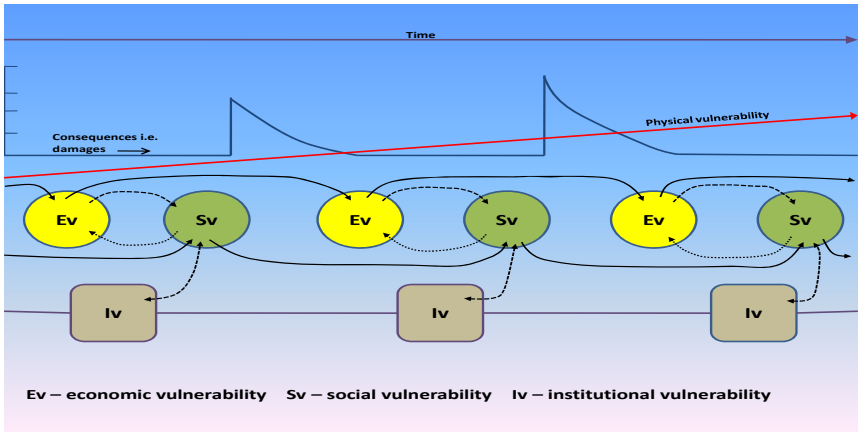


Figure 3: Economic and social vulnerability relations as 'influence-feedback-influence cycles' over time with inputs of institutional vulnerability in a situation in which economic growth is leading to rising physical vulnerability (particularly exposure) and the consequences of periodic disaster events lead to consequence spikes (Source: ENSURE, T.2.1, Section 5, p. 69)

A note of caution is in order here in connection with the dimension of time as treated in this section and elsewhere. The cycles mentioned here can be very lengthy and this raises all sorts of questions with regard to what affects vulnerability, coping capacity etc. In a period of several years, let alone decades, we cannot predict the inputs that will affect the situation when another disaster strikes in the distant future. Everything is bound to be different then, from infrastructures and technology to the structure of the productive system and the social conditions. We wish to draw attention to the fact that during the full disaster cycle it is not only the processes associated with the disaster (or chain of disasters) that count, i.e. processes of vulnerability management, reconstruction etc. When the cycle lasts for a long period, the rest of the world does not remain unchanged. Several changes are certain to occur in the economy (e.g. change of product demand), in society (e.g. absorption of the unemployed in new forms of employment locally or in nearby locations), in technology (making obsolete pre-disaster production methods or transport facilities), at the regional, national or supra-national level (e.g. an upturn in the economy or a new configuration of international trade) etc. At the end of the cycle the overall image may be totally different irrespectively of what the disaster-stricken actors or the relief authorities do. The danger therefore is to attribute the vulnerability conditions which develop or remain at the end of a cycle as being the exclusive outcome of the actors' actions with respect to the disaster event. This is a pitfall we must avoid. The problem is that vulnerability at the end of the recovery – reconstruction stage will bear the marks of a host of other developments and factors.

3.4 Methodologies for approaching vulnerability evolution in time

3.4.1 Temporal fluctuations of the distinct vulnerability facets and their mutual interactions: critical factors

As indicated in section 3.2, unfolding of losses and hence vulnerability manifestation and evolution in time might be viewed in 3 alternative ways:

1. by addressing probable standard courses and sequences of types of vulnerability to stress and types of vulnerability to loss (and relevant determinant factors)
2. by identifying the different vulnerability stages in connection to (a) susceptibility to loss and (b) capacity to recover (for each case of vulnerability facet) and respectively determinant parameters
3. by indicating how certain vulnerability facets influence the development of others along the stages of a single event or over a period defined by a series of events.

With regard to the first approach it is important to remind that vulnerability to stress is restricted to only some aspects of physical and ecological vulnerability. All the other facets (institutional, systemic, economic, social, territorial) are actually cases of vulnerability to loss and their manifestation comes only after physical and ecological vulnerability to stress. Worth-reminding is also the fact that vulnerability to stress is dependent on the features of the stress (thresholds of these features), while vulnerability to loss is dependent on the intensity and other characteristics of the provoking losses (actually thresholds of these characteristics). A challenge here is to specify the critical – in each case – thresholds of stress characteristics and loss characteristics. Another challenge is to interpret and represent the transition from vulnerability to loss to vulnerability to new stress.

With regard to the second approach, it is important to qualitatively and quantitatively approach the vulnerability stages in correspondence with the disaster cycle stages. As already discussed in 3.2, the disaster stage is predominated by the vulnerability component that refers to "susceptibility to loss". Hence crucial query to be answered with regard to the "disaster stage" of vulnerability is susceptibility to loss of all exposed forms of capital in connection to the characteristics of the stress. Indeed in each case of hazard some forms of capital are influenced and exhibit losses while other forms are not impaired. Degree of losses or impairment depends on geographical exposure and the position of the exposed element in the social, economic, political, psychological, technological hierarchy). On the other hand the "emergency stage" of vulnerability is predominated by the interaction between susceptibility to loss and response capacity. The critical query here is how and to what extend response capacity might alter susceptibility to loss and vice versa. For instance, what happens if the forms of capital necessary and vital for response capacity have been susceptible to loss and vulnerable at the precedent disaster stage? Finally, vulnerability at the recovery stage seems to depend on the availability of accessible forms of capital which are conveyable to recovery. Here vulnerability is determined by previous stage losses – and hence vulnerabilities – and by the probable lack of the demanded forms of capital.

This approach can be largely facilitated by considering the role of resilience in supporting a system's coping/response capacity and hence in vulnerability changes over time. Resilience has been conceptualized in operational terms in the context of T.2.2 and D.2.2. Among the quoted definitions the following might be helpful to the present approach: "Resilience is the ability of a system (a) to develop inherent resources and means usable for response and recovery and/or (b) to extract means and resources from the social, economic, political and ecological environment to engage and commit them consequently for the purpose of own response and recovery or for improving own position". The case studies and conceptual models that will be developed in Chapters 4 & 5 might use or test the above definition as well as the key dimensions/features of resilience, those quoted in D.2.2, i.e. diversity, redundancy, self-organisation, innovation, memory, experience, learning capacity, transformability, cohesion, efficiency, resistance, robustness, collaboration, interdependency,

autonomy, resourcefulness, spatial pattern, networking, individual capacity, self-reliance, feedback, flexibility, spatial and temporal scale interactions.

With regard to the third approach this is perfectly illustrated by figure 5.2 of Del. 2.1.1 (see figure 3 above) showing *how economic and social vulnerability relations as "influence-feedback influence cycles" over time interrupted by inputs of institutional vulnerability lead up to rising physical vulnerability (particularly exposure) and the consequences of periodic disaster events lead to consequence spikes (in a wider context of economic growth).*

3.4.2 "Vulnerability Actor" as the master of vulnerability changes over time

The present methodology is based on the notion of "Vulnerability Actor" as an entity / system carrying vulnerability and being capable of performing response / management attitudes for the purpose of survival, recovery or effective adaptation to adverse events (shocks) and hence for the purpose of reducing own vulnerability (see section 3.1). The above response attitudes and their impact on actor's own vulnerability vary over time, i.e. from one stage of the disaster cycle to the next and from one catastrophic event to those that follow. It becomes evident that vulnerability changes in time are dependent on the above response attitudes and that it is essential for our analysis to examine the standard features of such responses in a systematic way. Essential is also the examination of the respective impacts on vulnerability of both the Actor taking the initiative and others as well. Such a systematized analysis might include the following steps:

(a) Address the Actor performing the response process and identify the disaster cycle or cycles of concern;

(b) Approach the Actor's initial vulnerability by identifying actual (or potential) losses (referring to the types of capital accessible to or controllable by the Actor);

(c) Identify the resources (forms of capital) committed to the response process (performed by the Actor), its spatial and temporal range and respective modus operandi;

(d) Assess the final outcome, i.e. repercussions on own and other Actors' vulnerability.

The above steps are described and explained further in the following paragraphs.

(a) *Address the Actor performing the response process and identify the disaster cycle or cycles of concern:* Once a researcher centres its interest on a specific hazard confronted over time or a specific disaster cycle, he/she will obviously locate numerous Actors attempting to manage their multi-faceted vulnerability. However, specific types of Actors appear again and again (for instance in the context of a specific disaster cycle) to display standard behaviour and response against their vulnerability. For instance, after the Mt Parnitha earthquake (Athens 1999) and in the recovery period most of the Small Manufacturing Firms in Western Athens avoided public support for recovery and the relevant "expensive" statutory procedures. Instead they favoured solutions externalizing recovery costs, such as gaining support from their suppliers in the form of credit, making extemporary self-repairs, proceeding to dismissals, failing to pay forced contributions etc. Evidently here, a micro-scale Actor performs a standard behaviour towards its vulnerabilities: The Actor prioritizes curing of its short term economic vulnerability by deteriorating its physical in the long term and by transferring social vulnerability to "the controllable" powerless social Actors. In this example it is worth noting that the Actor "Small Manufacturing Firm" covers not only the economic organization but all sorts of its constituting elements or attached assets (i.e. the controllable and accessible by the firm forms of capital). It is also worth noting that the Actor's decisions regulate vulnerability

of all attached to the Actor forms of capital. Hence, identification of the Actor includes also localization of the various forms of capital attached to this Actor.

(b) *Approach the Actor's initial vulnerability by identifying actual (or potential) losses (referring to the types of capital accessible to or controllable by the Actor):* Here, the researcher's study should cover all forms of vulnerability at stake, short and long term, physical, social, economic, systemic, i.e. all those suffered by the Actor. Hence, of interest are all forms of loss, failure and exposure (actual and anticipated) of the capital attached to the Actor. In the case of the Small Manufacturing Firms mentioned above, possible losses and failures include material and immaterial ones (building damages, loss of lives among the labour force, interruption of water, energy, communication and other supplies, loss of clientele, loss of suppliers, turnover reduction, prospects of closure). To use another example, households may suffer as a result of an earthquake disaster, from loss of lives, loss of sources of income, property losses and/or become homeless and displaced from friendship and neighbourhood networks.

The researcher who investigates Actor case histories out of s disaster event has to record both the manifested aspects of vulnerability and those that were not ever manifested because of the choices and respective responses of the Actor himself who intervened and intercepted this manifestation.

(c) *Identify the resources (forms of capital) committed to the response process (performed by the Actor), its spatial and temporal range and respective modus operandi:* The resources and mechanisms employed by an Actor during Actor's response process are the most determinant factors of the final outcome, i.e. the impact of this process on Actor's own and others' vulnerability. The resources tapped in an adaptation process (in pre-disaster terms) or a response/coping process (in post-disaster terms) is resources extracted from the then accessible or reachable by the Actor forms of capital (natural, financial, human, social and physical). However, the researcher should bear in mind that the pools of resources which the Actor appeals to in the emergency and recovery period are not the same as in pre-disaster terms. In post-disaster contexts emerge new and extraordinary forms of capital that are latent, inaccessible or completely missing in normal periods (Sapountzaki 2007, see also T.2.2, section 7.d).

Examples of such extraordinary resources are ad-hoc disaster recovery funds, post-disaster networks of social trust and solidarity, opportunities arising from the disruption of formal rules and statutory regimes of normal periods, networks of donation and special financial support, special recovery-oriented institutions, prior experience and respective social knowledge, memory and ethics, parallel structures of illegality etc. For instance, in post earthquake and other emergencies, and only then, public space may be available to private occupation by the homeless, for the purpose of emergency sheltering. These resources (material and immaterial) are very useful to recovery and combating own vulnerability during this late stage of the disaster cycle. As mentioned in T.2.2 (section 7.d)the Actors who manage to engage and employ a larger part of the available post-disaster capital, these Actors will probably achieve higher rates of vulnerability decrease and lower eventual levels of vulnerability (out of the disaster cycle). But these "successful Actors may dispossess other Actors (individual or collective) from resources vital to their recovery and hence restrict their possibilities for vulnerability reduction. Indeed, post-disaster arenas are fields of struggle and competition among Actors for recovery resources. Public policy measures are only one among several types of such resources. Besides, institutions are themselves one of the several types of Vulnerability Actors.

One important issue for identification and recording of the resources committed to Actor's response against own vulnerability (and resulting to vulnerability redistribution in time and space) is the spatial and temporal range/scale of these resources. Actors strive

to attract the resources they need for coping and adaptation from a whole range of scales and levels of socio-economic, physical, institutional space. For instance, private individuals seek the support of family members as well as neighbours, community associations, even expatriate relatives and friends in foreign countries. All those facing an adversity recall all potentially accessible resources, both those at hand and those remotely available (Sapountzaki 2007, see also D.2.2, section…). An actual example quoted in an article by Sapountzaki (2007) will probably illuminate this general principle:

> *"When the head of a household affected by a disaster sends the most vulnerable family members off to distant relatives away from the stricken area and at the same time stays in a temporary emergency shelter provided by the government in order to supervise the reconstruction of the damaged family house, he/she conducts a process appealing simultaneously to three scales or levels: That of the site of the households' landed property, that of the space of the households' social and kinship networks and a third one of the Governmental level provisions".*

Recording of the resources employed by an Actor during the adaptation to or coping with a hazard and vulnerability process might be accommodated by the following table (Table 1).

It goes without saying that the eight columns are not alternatives. The categories of the first five columns (forms of … capital) could easily become sub-categories of the categories of the last three columns and vice versa.

Table 1: Identity of resources employed in adaptation and response/coping processes by Vulnerability Actors

Resources / *Stages of the disaster cycle*	*Forms of Natural Capital*	*Forms of Economic Capital*	*Forms of Human Capital*	*Forms of Social Capital*	*Forms of Physical Capital*	*Extraordinary forms of post-disaster capital*	*Spatial scales / levels appealed to by the Actor*	*Temporal scales/ range of tapped resources*
Pre-disaster adaptation								
Post-disaster response								

(d) *Assess the final outcome, i.e. repercussions on own and other Actors' vulnerability:* The aim of this step (and with reference to the time span of a single disaster cycle) is assessment of the residual vulnerability, i.e. the part of vulnerability that the Actor retained (after the efforts of adaptation and response) at the end of the recovery reconstruction stage. This end is at the same time the starting point of the subsequent disaster cycle.

This is actually a study of vulnerability balance and its results might appear in tables / matrices constructed for this specific purpose as it is shown below (Tables 2, 3, 4 and 3.5).

Table 2: Internal rebalancing of vulnerability facets by Actor X

Rebalancing the facets / Stages of the disaster cycle	*Physical*	*Social*	*Economic*	*Systemic*	*Institutional*
Pre-disaster adaptation					
Post-disaster response					

O No change, - Reduction, + Increase

Table 3: Internal redistribution of vulnerability to the disaster stages and to new hazards by Actor X

Re-distribution in time & to other hazards / Stages of the disaster cycle	*Vulnerability in pre-disaster terms*	*Vulnerability of the emergency period*	*Vulnerability during recovery / reconstruction*	*Vulnerability to the next event and/or new hazards*
Pre-disaster adaptation	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*
Post-disaster response	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*

O No change, - Reduction, + Increase

Table 4: Internal transfer to other Actors by Actor X

Transferring Vulnerability to other Actors / Stages of the disaster cycle	*Social Actors (specify)*	*Economic Actors (specify)*	*Institutional Actors (specify)*	*Eco-human / Territorial systems (specify)*	*Other (specify)*
Pre-disaster adaptation	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*	*Social? Physical? Economic? Institutional? Systemic?*
Post-disaster	*Social?*	*Social?*	*Social?*	*Social?*	*Social?*

response	*Physical? Economic? Institutional? Systemic?*	*Physical? Economic? Institutional? Systemic?*	*Physical? Economic? Institutional? Systemic?*	*Physical? Economic? Institutional? Systemic?*	*Physical? Economic? Institutional? Systemic?*

O No change, - Reduction, + Increase

Table 5: Actor's X additional vulnerability coming from other Actors

Additional vulnerability coming from other Actors / *Stages of the disaster cycle*	*Physical*	*Social*	*Economic*	*Systemic*	*Institutional*
Pre-disaster adaptation	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*
Post-disaster response	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*	*Specify the accountable Actors*

O No change, - Reduction, + Increase

In cases of Territorial and Eco-human systems it is obvious that these involve multiple types of Actors where each Actor type represents numerous Actor cases. The deductive approach is inevitable in such cases; the researcher has to elevate the predominant Actors in each stage of the disaster cycle to study consequently vulnerability transferences between them, internal temporal re-allocation and vulnerability rebalancing for the group of the pre-dominant Actors to finally estimate vulnerability balances at the end of the recovery phase.

A similar approach can be followed -after appropriate adjustment- for a longer period covering more than one disaster cycles. In this case one has to consider changes in vulnerability balances after each successive disaster cycle.

The prescribed method pre-supposes data availability as regards response attitudes of specific exposed or victimized Actors from mitigation to recovery and overall impact of these behaviours on own and others vulnerability. It presupposes also data availability as regards attitudes of other Actors, those that can have an influence on the vulnerability of the specific Actor under examination.

The above presented methodology is reflected in the contents /structure of Chapter 6 below.

4. Patterns of vulnerability evolution from the pre-disaster to the recovery phase

Vulnerability, regardless of its scope/filed of reference (e.g. a government agency, a social unit, a territorial unit), element or system passes through the successive stages of the disaster cycle. These vulnerability fluctuations are reflected in the distinct and different types of losses experienced by the carrying agency in specific spatio- temporal location. Independently of the threat/ disaster encountered vulnerability changes refer to:

- The carrying agency: Each stage of the disaster cycle is featured by different predominant vulnerability carriers. For instance, in the emergency phase predominant

vulnerability carriers could be the authorities and mechanisms responsible for emergency operations (resque, emergency hospital care, evacuation etc.) and all those who depend on their operational capacity; in the recovery phase predominant vulnerability carriers as the authorities responsible for policies providing support to recovery and reconstructions and of course of all potential beneficiaries of their support.

- The referred type of hazard or threat (e.g. building that has been hit by a forest fire may prove vulnerable to seismic hazard too)
- The types of losses vulnerability might result in: During disaster crises at stake are physical, human and ecological losses (buildings, human lives, technical infrastructure etc.) while in recovery phases at stake are restorations, re- functioning, regenerations etc.
- The origins of vulnerability, e.g. whether vulnerability is due basically to propensity to loss or incapacity to recover
- The level/ degree of vulnerability, e.g. an unrepaired building structure is more vulnerable at the recovery phase compared to its situation in predisaster terms

The reasons of causal origins of vulnerability fluctuations vary also:

- Hazard fluctuations through time entail respective vulnerability changes (indicative is the cave of volcanic eruptions)
- Response capacities and resilience determine also increases and decreases of vulnerability. This is more obvious in the recovery/ reconstruction period but it holds also true in predisaster terms. Variability is an inherent feature of vulnerability. It is note mostly that this variability and especially the potential for vulnerability decrease is influenced by risk and vulnerability perception

The present chapter includes two sub- chapters. Sub- chapter 4.1 devoted to the patterns of evolution of several facets of vulnerability; section 4.1.1 illustrates a care where vulnerability changes are due to hazard transformations (the case of Vesuvius Volcanic eruptions) while Section 4.1.2 illustrates a case where vulnerability increases and decreases are the result of resilience practices response/adaptation processes. Sub- chapter 4.2 is devoted to the patterns of loss sequences along the successive stages of a disaster cycle; Section 4.2.1 deals with wild fires in Australia and the respective losses in properties, forest ecosystems and human lives while Section 4.2.2 deals with the patterns of propagation of flood losses (in the case of Katrina disaster) as well as the diverse rates of recovery from these losses.

4.1. The dynamics of distinct types of vulnerability and of mutual interactions – Determinant factors.

4.1.1. Dynamics of Hazard determining temporal vulnerability changes: The case of Vesuvius Volcanic Eruptions

a. Introduction

Volcanic eruptions are useful case-studies to better explore the relationships existing among temporal changes of vulnerabilities with reference to the different phenomena occurring during a volcanic event.

Vesuvius is a high risky volcanic complex, because of its eruptive type, which is predominantly explosive and because of its proximity to the densely populated urban area of Naples.

Starting from the Fifties, the metropolitan area of Naples, that has at present about 3 millions of people, has been subjected to relevant phenomena of intensive urbanization, increase of population and growth of illegal buildings: therefore, it is currently one of the most densely populated volcanic region in Europe.

The last Vesuvius' eruption occurred in 1944, but its eruptive history is well-known and has been largely faced by volcanologists: "Vesuvius often experienced long periods of quiescence that lasted, in some cases, centuries or tens of centuries, with an awakening more and more violent the longer the repose-time preceding the eruption was" (Cioni et al. 2003). The most recent plinian events occurred in A.D. 79, A.D. 472 and A.D. 1631. "Alternating with these major eruptions, several smaller explosive eruptions occurred" (Cioni et al. 2003). The 1944 eruption started the new phase of activity (with obstructed conduit) which currently characterizes the volcano.

b. Temporal evolution of volcanic hazard and temporal changes in damages and vulnerabilities

Volcanic eruptions are characterized by temporal phases with different volcanic phenomena that show variable durations and hit different areas and territorial targets. The temporal evolution of a volcanic event involves therefore extremely remarkable temporal and spatial variations.

The survey on temporal variations of vulnerability is not an easy task and directly feasible, especially in relation to events, such as volcanic eruptions, which are so articulated over time. This type of survey is, indeed, an indirect operation based on the analysis of damages occurred during an hazardous event, meant as tangible outcomes of the vulnerabilities of the hit territorial systems.

The temporal evolutions of volcanic phenomena during a plinian or sub-plinian eruption, like the Vesuvius' historical eruptions, have been studied in depth by volcanologists. Such eruptions are characterized by a big initial explosion, producing an eruptive column of gas and solid particles (pumices, ashes and lithic fragments). The explosiveness of the eruption is caused by the magma fragmentation because of magma gases decompression or instantaneous vaporization of water when in contact with magma. An eruption can be generally considered as a group of well-defined eruptive phases (for instance, phreatic, plinian, phreatic-magmatic phases, like in the Vesuvius case in 79 A.D.). Based both on the plinian eruption of 79 A.D. and of the 1631 event, the likely temporal frequency of a subplinian eruption for the Vesuvius can be outlined as follows:

0 Precursors of the event.

1 Phreatic-magmatic vent of the conduit, opening of the obstructed conduit by the explosion, rising of the eruptive column, ballistic projectiles and debris of the explosion as far as 2-3 km from the eruptive vent, initial fall of ashes as far as 10 km from the volcano vent, moderate to strong earthquakes; the phase lasts from one to several hours; the overall affected area is about 10 km^2.

2 Sustained eruptive column reaching the altitude of 20 km, start of pyroclastic fragments, ballistic projectiles as far as 3-5 km from the crater, continuous very intense earthquakes; phase length about 5 hours; the overall affected area is about 150-200 km^2.

3 Sustained eruptive column in altitude, beginning of ashes dispersal produced by prevailing winds, deposit of pyroclastic debris on the ground producing roofs collapse

as far as 10-30 km from the crater, possible partial collapses of the column with lateral pyroclastic flows; the phase lasts about 12 hours; the overall affected area is about 200 km^2.

4 Collapse of the eruptive column with pyroclastic flows, ashes dispersal goes on, strong but isolated earthquakes, possible collapse of the cone top, tsunami; phase length 4 hours, the overall affected area is about 120 km2 (peak phase).

5 Rains and last ashes deposits, explosion of the conduit produced by water-magma interaction, trigger of lahar, or flow of ashes and pyroclastic deposits triggered by volcanic rain; this phase lasts few days, the overall affected area is about 150 km^2.

6 End of the eruption.

In these temporal phases, which can last for different times, different volcanic phenomena (fig. 1), which have heterogeneous impacts on settlements, may occur. Each of the outlined phases is characterized by different phenomena which can be very rapid as earthquakes, pyroclastic flows, tsunami and lahars or that can last for days or a long time, as pyroclastic falls (ashes, pumices, lapilli, etc.).

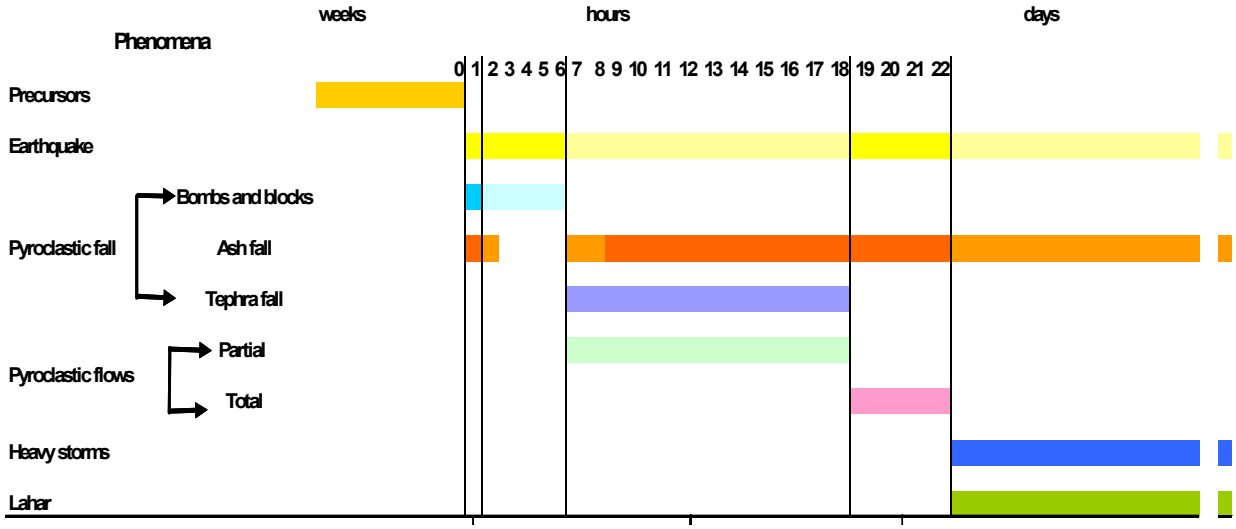


Figure 4: Volcanic phenomena in the temporal phases

The described temporal sequence points out the dynamic features of the volcanic event. During each phase different areas affected by different phenomena or with different intensities alternate and overlap. Moreover, the affected area during the different temporal phases is strictly linked to types and intensities of phenomena. In each temporal phase, different territorial elements are hit by different volcanic phenomena and, consequently, different types of damages with different levels of intensity occurred. The vulnerabilities of the territorial systems interact with the volcanic hazards producing impacts and damages.

Within the SCENARIO Project founded by European Commission, in order to set up a scenario of possible Vesuvius' eruption, the main types of damages which may occur during a volcanic explosive event have been singled out in a qualitative way and basing on the available description related to past Vesuvius' eruptions (fig. 5).

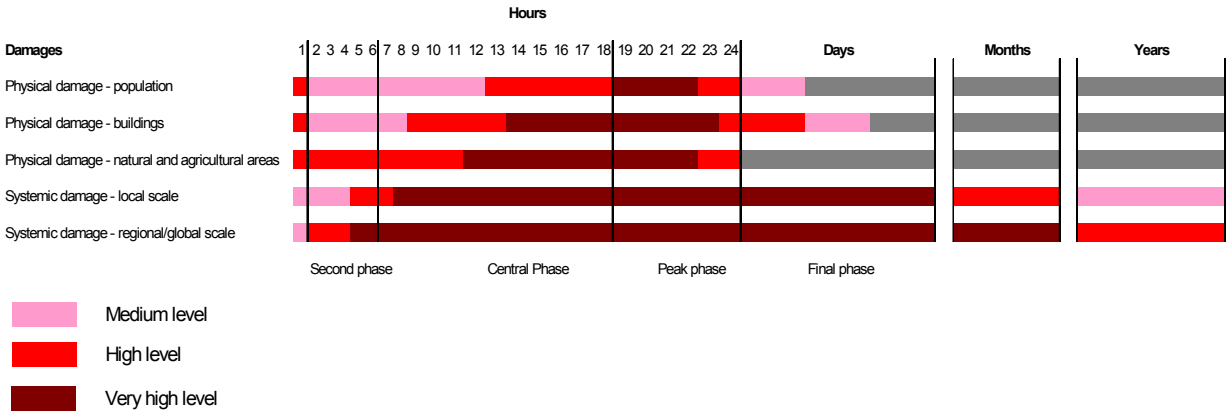


Figure 5: Qualitative intensity level of damages during the explosive eruption phases

The figure highlights the temporal occurrence and the level of intensity of physical and systemic damages during an explosive eruption.

Physical damage may increase in the peak phase, characterised by pyroclastic flows and ashes falls. The damages to people, for example, are more relevant during the peak phase in consequence both of the pyroclastic flows and of the ash deposits which become so relevant that may induce the collapse of roofs. During a plinian eruption, the different phenomena hit different territorial targets. Physical vulnerabilities of different territorial targets play different roles and are activated in different time periods in relation with the different phenomena which may occur. As an example, while pumices and ashes can cause the collapse of roofs and the loss of crops and breeding without being fatal for people in that they have the chance to run away, pyroclastic flows, due to their fast spreading as well as of their high temperatures, destroy everything along their path, preventing, in such a way, every possibility to run away. People being not directly hit by the flows can either undergo great damages or die for burns or suffocation. Moreover, the overlapping of the effects of different phenomena on the same territorial systems in different times produces changes in physical features of the territorial systems and, consequently, in their physical vulnerabilities.

The previous graph shows how during an eruption, unlike other natural hazards (such as earthquakes), volcanic phenomena may induce immediate systemic damages, which may increase during the time. Although systemic and long term economic impacts have been always present in volcanic events, these kinds of vulnerabilities emerge with more clarity in hazardous events affecting urban systems characterized by an high level of complexity. The Vesuvius' eruption scenario tried to highlight different aspects of systemic vulnerability due to volcanic event in large complex urban systems. The worked out scenario singles out the main systemic impacts which may occur in the different phases of the eruption and their duration (table 6). For example, in the Vesuvius' case, many aspects of systemic damages have been highlighted like the interruption of the flight connections due to volcanic ashes occurring in the first phase of eruption and lasts until the final phase of the eruption at least; the interruption of passengers and freight flows, interruption of tourist flows with large consequences on tourist industry, blockage of the export activities. Other systemic impacts can be referred to the atmospheric effects of the eruption column that could generate frequent lightning phenomena, responsible for generating magnetic fields that can, in turn, may induce breakdown in communications and, consequently, may reduce the effectiveness of rescue activities.

Table 6: Systemic impacts during the eruption temporal phases (from SCENARIO Project)

Phases / Targets	First phase	Second phase	Peak phase	Final phase	Post-event medium term	Post-event long term
Agricultural areas	Blockage in agricultural activities				Blockage in export of agricultural goods	
Forests				Air pollution due to CO_2		
Network infrastructures	Interruption of flight connections	Breakdown in communications				
Transport nodes and other infrastructures		Interruption of passengers and freight flows				
Commercial and Industrial areas		Blockage in commercial and industrial activities			Blockage in food industry Blockage in export activities	
Monuments	Interruption of tourist flows		Loss of world heritage			
Climate				Change in climate conditions		

c. *The history of Vesuvius' eruptions*

As above mentioned, the main aspects related to temporal dynamic of vulnerabilities in volcanic events, can be synthesized as follows:

- different types of vulnerabilities play different roles, assuming different relevance, during the different phases of the eruption;
- changes in exposure and vulnerabilities of exposed elements during the different phases of the eruption;
- vulnerability to combined events due to the temporal overlapping of different phenomena;
- some types of vulnerabilities manifest their effects for very long time after the event.

In this paragraph, each point of the previous list will be further explained through some examples of past Vesuvius' eruptions.

For what concerns the first point, we can refer to the Vesuvius' eruption of 4th of April 1906. The eruption started at 5:30 a.m., with a little lava flow and during the following two days, other vents opened with emission of lava flows which didn't threaten the urban centres (Civetta et al., 2004). The explosive activity reached its maximum intensity in the night between the 7th and the 8th of April. On the 9th of April, in the afternoon, while the pyroclastic falls were still falling down, the main lava flows and the seismic activity ended. On the 10th of April in Naples the roof of a market collapsed due to the pyroclastic falls accumulation, provoking 11 dead and 30 injured. During the night the last lava flow ended. The eruption ended on the 21st of April and provoked 216 dead, 112 injured and over 34000 homeless. This example highlights that volcanic eruptions are characterized by different temporal phases corresponding to different hazard phenomena with heterogeneous impacts. With reference to these kinds of hazards, the characteristics of exposure of the territorial system are variable also in the short time. For example during the first phase of the described eruption, the effusive activity didn't threaten the population which have been prone to pyroclastic falls and flows during the following explosive phase of the eruption.

From one temporal phase to another, changes in vulnerability of exposed elements are very fast. The second eruptive phase of 1631 eruption, occurred during the night between 16th and 17th December, was characterized by several moderate explosions (Rolandi et al., 1993). Those explosions were capable of throwing blocks in a range of 2-3 km from the

crater, producing only a weak fall of ashes in the plain to the east of the Vesuvius. The amount of material produced in this phase was modest and the effects on built up areas were marginal. However, the pyroclastic flows, occurred on the following morning, by flooding along the Vesuvius sides destroyed, in 2 hours, several villages not damaged by the lapilli fall during the previous plininian phase (Rosi et al., 1993).

Vulnerability of exposed elements is a dynamic feature changing in relevant manner during the volcanic event. In many cases, during an eruption, the same territorial elements, such as buildings and infrastructures, may be hit in different times by the same volcanic phenomenon (for example the ashes in the beginning and at the end of the eruption) with a progressive increasing of physical vulnerability due to the reduced capacity to face the impact of the volcanic phenomenon. In some cases, the same territorial elements are hit by different phenomena, for example ashes and pyroclastic flows. Moreover, the behaviour of people during the event can determine changes in the exposure and vulnerability during the different volcanic phases. For example, the exodus from the hit area modifies not only the population exposure, but also the vulnerability conditions with reference to some volcanic phenomena. The famous 79 A.D. Vesuvius' eruption was characterized by three main eruptive phases described in-depth by Plinius. The eruption showed phases with different intensity. The archaeological excavations showed many bodies contained in the ashes erupted during the final phases of the eruption, since in many cases, the people going away during the pumices fall came back later and were killed by pyroclastic flows. Indeed, what might have occurred is a reduction in the intensity of eruption between the first phase and the occurring of pyroclastic flows.

For what concerns combined events and temporal aspects, we can provide an example. The final phase of the 1631 eruption was characterized by mudflows and floods produced by strong rains. In a wide area surrounding the Vesuvius, many houses had their roofs collapsed because of the humid ashes heap. Humid ashes have a high specific weight1 and even with small thickness they can cause the collapse of roofs. Considerable mudflows were exacerbated by the waterproofing of the ground covered by the ashes fall, which stopped the regular absorption of rainwater.

For what concerns systemic vulnerability and long term effects of economic vulnerability, they are always present in volcanic events. Dead people, physical and economic damages caused by the Vesuvius' 79 A.D. were huge, not only the ones to villages and population, but also the long-lasting systemic ones. The regional economy was damaged and in particular wine production as well as garum export stopped. It was not by chance that after the eruption Rome began importing wine and other products from Gallia and no more from Campania. The eruption consequences mainly scattered toward south-south-east direction, but also the north and west areas, although avoided dead and destruction, were affected by heavy economic consequences. Few centimetres of ashes and pumices can compromise agriculture for long time: cultivation all over Campania might have been destroyed with consequent famines, loss of cattle because of forage shortage and diseases.

More recently, during the Second World War, for example, the 1944 Vesuvius eruption provoked serious damages to the military airport built up in Terzigno, destroying some equipment of the American forces and causing the stop of the military actions in the area.

4.1.2 Vulnerability fluctuations determined by Resilience: The case of economic vulnerability of the local population in St. Bernard Parish, hurricane Katrina disaster

[1] Specific weight is calculated as weight for unit of volume.

Financial vulnerability is the susceptibility to, or potential for, financial deprivation arising from a combination of limited financial circumstances prior to a disaster, the financial losses suffered as a result of a disaster and incapacity to recover from these losses.

Financial deprivation may arise form one or a combination from a relatively large number of contributory factors including, for example, below average levels of income, limited or negligible savings, debt, lack of access to cash and credit, disability or ill-health which limits income earning capacity, limited access to welfare funding or dependency on such funding, termination of wage payments owing to disaster, lack of access to wider family or other finances and social capital which can aid financial recovery, and lack of disaster insurance.

The case study drew on a very rich variety of secondary sources including published texts and journal papers, and extensive web-based sources including demographic data from census and local authority web-sites. Hurricane Katrina's impact On New Orleans, and St Bernard parish in particular, was so dramatic that it led to a particularly extensive and informative set of web sources including, for example, detailed descriptions and animations of the flood and its effects and the affected communities, impacts on particular population segments, legal documents, company documents, and the web pages of environmental regulators, faith and other special groups, aid and recovery agencies, environmental watchdogs, news media and blogs of individuals affected by the disaster.

a. Introduction

This case study of a parish within New Orleans focuses on economic vulnerability, but in the context of physical, social and institutional vulnerability. For the general description of the disaster of flooding and chemical spillage in St. Bernard Parish, New Orleans following hurricane Katrina see section 6.1.2 and Del.2.1. The form of economic vulnerability in this case study may be defined as financial vulnerability i.e. the financial vulnerability of members of the population of St Bernard Parish. The case study is based upon an analysis of financial vulnerability by disaster phase which acts as a proxy for time.

b. Differentiating vulnerability by population segments

The vulnerability of a local parish population of 66,000 (i.e. the pre-Katrina population) cannot be treated homogeneously without making large generalizations. Instead, we can begin by conceptualizing financial vulnerability to flood and oil contamination at the level of the individual. In this atomized conceptualization, each individual possesses their own unique (or almost uniquely differentiated) financial circumstances and vulnerability. Even in the same household, dependents will have a different financial vulnerability to the household breadwinner. However, dealing with such a large number of differentiated vulnerabilities is impossibly burdensome, and so we can turn to identifying groups of individuals with some degree of potential homogeneity. There is a large number of ways of segmenting a local population, but in this case study eight segments are employed. These are not necessarily mutually exclusive segments. These eight segments are:

- those who died in the disaster (150+);
- those who are disabled in some way: circa 15,000 i.e. 23.4% of the community total were disabled in the pre-Katrina period (National Organisation for Disability, 2006) but here we focus on the most disabled quartile of circa 3,750 people;
- the family members of those who died 1) breadwinners 2) non-breadwinners;
- those who resettled permanently in another location (number unknown but somewhere between circa 1,000 and 36,000);
- those who returned to the community after the disaster (3,361 by 1 January 2006, currently circa 33,000);

- those who are yet to return to the community (number unknown but somewhere between circa 1,000 and 33,000);
- those who are business owners (about 1,000+ businesses prior to Katrina; the Parish had 17,500 jobs in August 2005, this declined to 8,200 one year later as a consequence of the disaster); and
- those who are oil company employees (Murphy employees = circa 300).

It is of course feasible to segment the population in alternative ways, some of which may be more pertinent to financial and other facets of vulnerability than others. For example, segmentation might be by age, gender and race and ethnicity. Many of the disabled are elderly. St Bernard parish is predominantly white but there are significant minorities (www.epoducnk.com/cgi-binInfo.php?locIndex=3566), and there is some indication that some of these minorities suffered higher degrees of financial deprivation than the majority grouping.

c. Economic vulnerability analysis – methodology

The economic vulnerability analysis was performed using secondary source data accessed principally by internet. St Bernard Parish and the Katrina disaster are, fortunately, both data rich subjects which allow such an approach to be followed. The analysis was performed using a matrix which tabulates the eight population segment against four disaster phases, describing the predominant vulnerability (Table 7). For example, in some cases many different sources of financial vulnerability may be present, but the analysis focuses upon describing the predominant vulnerability.

Three types of vulnerability are recognized:

1. Susceptibility to stress (applies to physical vulnerability only in this analysis)
2. Susceptibility to, or potential for, loss
3. Capacity to recover

Three 7-point categorical scales are used to describe vulnerability as follows:

a) a depth of vulnerability (DV) scale applies to 1 and 2 above
b) a capacity to recover (R) scale applies to 2 above
c) a) and b) together (i.e. depth of vulnerability plus capacity to recover) are represented in a further scale (DRV)

Table 7: Categorization of vulnerability by type

Depth of vulnerability (DV)		**Capacity to Recover (R)**		**Recovery capacity and depth of vulnerability (DRV)**	
DV7	Extreme	R7	None, virtually none	DRV7	Extreme
DV6	Very severe	R6	Very severely limited	DRV6	Very severe
DV5	Severe	R5	Severely limited	DRV5	Severe
DV4	Serious	R4	Impaired	DRV4	Serious
DV3	Less than serious	R3	Less impaired	DRV3	Less than serious
DV2	Moderate	R2	Good	DRV2	Moderate
DV1	Minor	R1	Excellent	DRV1	Minor

It is important to recognize that the scales are categorical and not interval scales. It cannot be inferred that the categories are somehow evenly spaced along a measurement scale, and also it is not possible to add categories. DRV is not derived from an arithmetic addition of DV plus R, but is arrived at by considering the overall severity of both.

Not surprisingly, because the disaster in St Bernard parish was extremely severe, the upper half of these vulnerability scales tends to be utilized mostly in this case study, but an advantage of using a 7 point scale is that the method may be used to compare vulnerability levels in less severe disasters. It is easy to underestimate the effect that resilience can have in reducing vulnerability. This case study methodology attempts to recognize the positive effects of resilience in reducing vulnerability.

In Figure 6 the difference between the height of a vulnerability column and the top of the vulnerability scale (e.g. for those who died, this is the difference in the pre-disaster period between DV6 and DV7) is, in theory, a measure of two components. The first is the difference between assessed vulnerability for a particular disaster and the maximum possible vulnerability. For example, a disaster which is less severe might lead to a lower vulnerability than was the case in Katrina. The second component is a measure of resilience which reduces vulnerability downwards from the maximum possible vulnerability. Since Katrina is an example of an extreme, catastrophic disaster, in this case the difference between each column and the top of the scale is effectively a measure of resilience.

The analysis is performed in Appendices Table I which provides a vulnerability landscape for the local parish population for the Katrina disaster through each of its phases between 2005 and early 2010. Because of the severity of the disaster, the recovery and reconstruction period will be lengthy and could be as long as several decades. This economic vulnerability landscape for the 4+ year period analyzed is summarized and displayed in Figure 6. Table I in Appendices and Figure 6 reveal a regular transition in vulnerability type over time. In the two post-disaster phases, especially through the DRV methodology, we recognize that vulnerability is made up of vulnerability to loss, because the area remains exposed and vulnerable to a further event, plus the capacity (or incapacity) to recover.

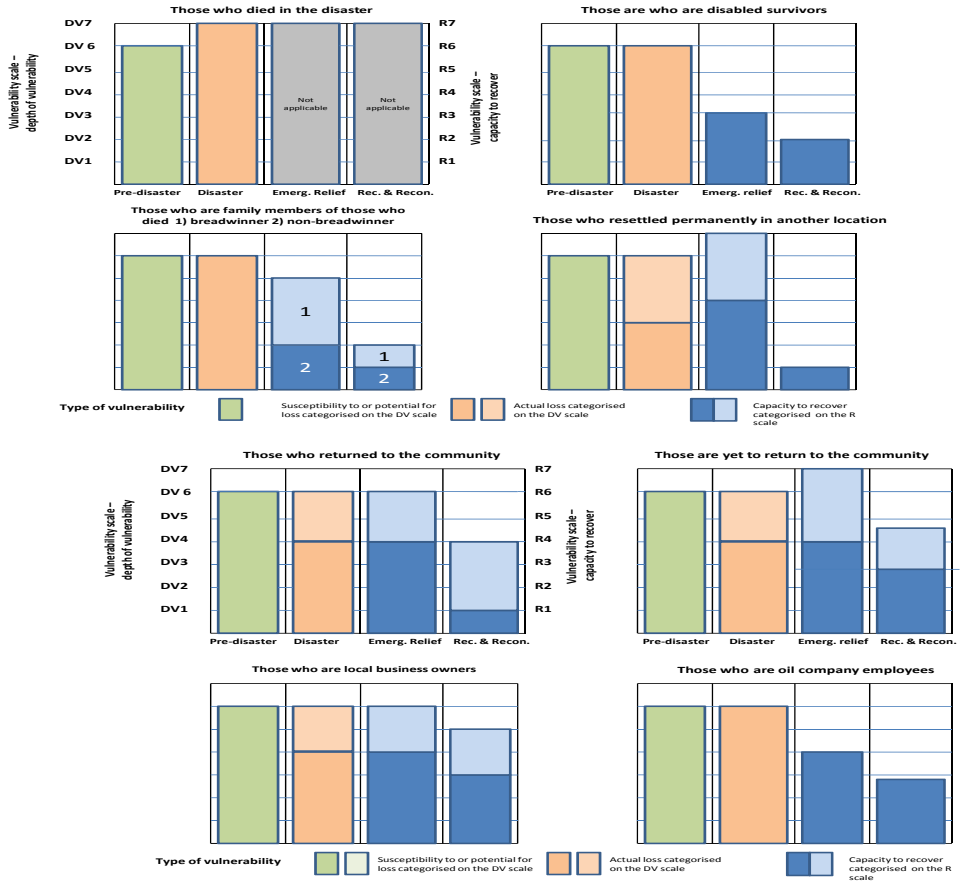
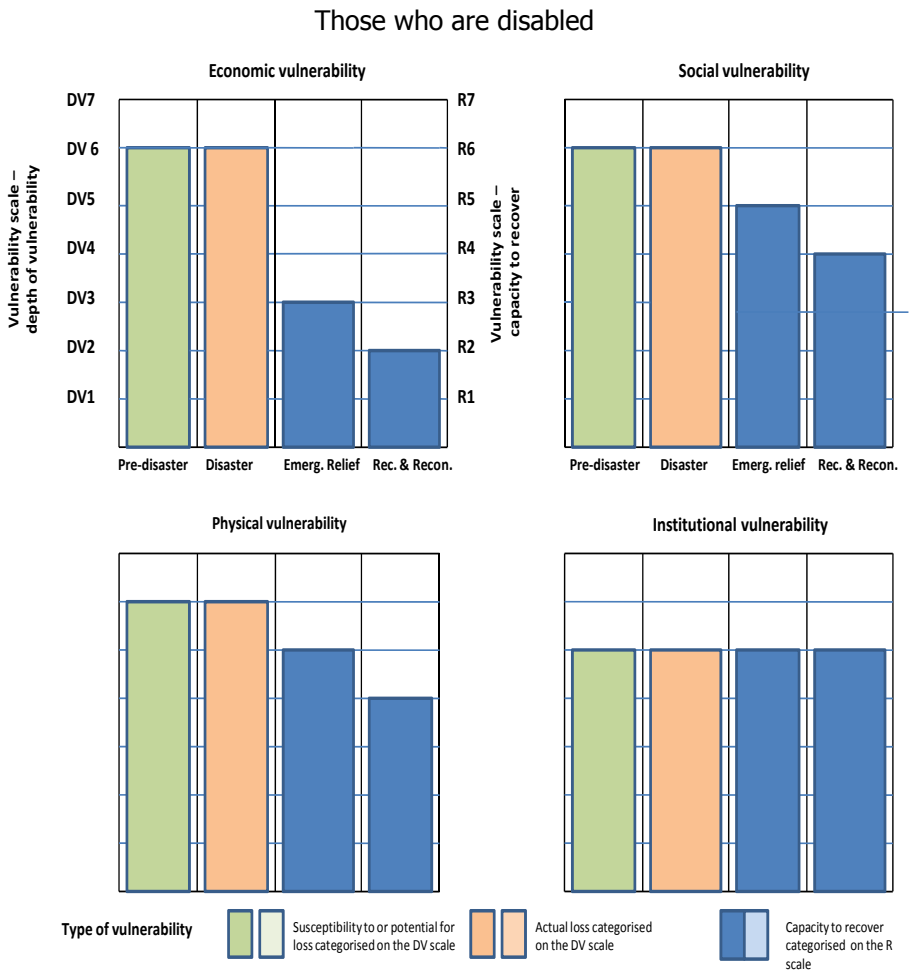


Figure 6: The economic (i.e. financial) vulnerability landscape: St Bernard Parish, New Orleans, Katrina hurricane flood and oil contamination disaster, 2005 to 2010 (with the flood and oil contamination disaster viewed in isolation in time)

Table I in Appendices attempts to identify where resilience is particularly significant in reducing vulnerability, although resiliences are much more complicated than displayed in Table I in Appendices (see Appendix). Table I in Appendices also indicates where scale effects are likely to be particularly significant. The orange arrows in Table I in Appendices are an attempt to identify the principal linkages between different facets of vulnerability, although in reality these linkages are more complex than it is feasible to show in Table I in Appendices and Figure 6 demonstrate just how severe financial vulnerability has been for the different segments of the local population, and just how much further the community has to go before financial vulnerability is minimized. The figure also reveals the differentiated fortunes of the local population. For example, oil company employees appear to have faired better than local business owners who need to be differentiated according to their experience. It is difficult to summarize the changing vulnerability of those who died and to apply this to the post-disaster period, and in Table I in Appendices and Figure 6 post-disaster vulnerability is categorized as being inapplicable.



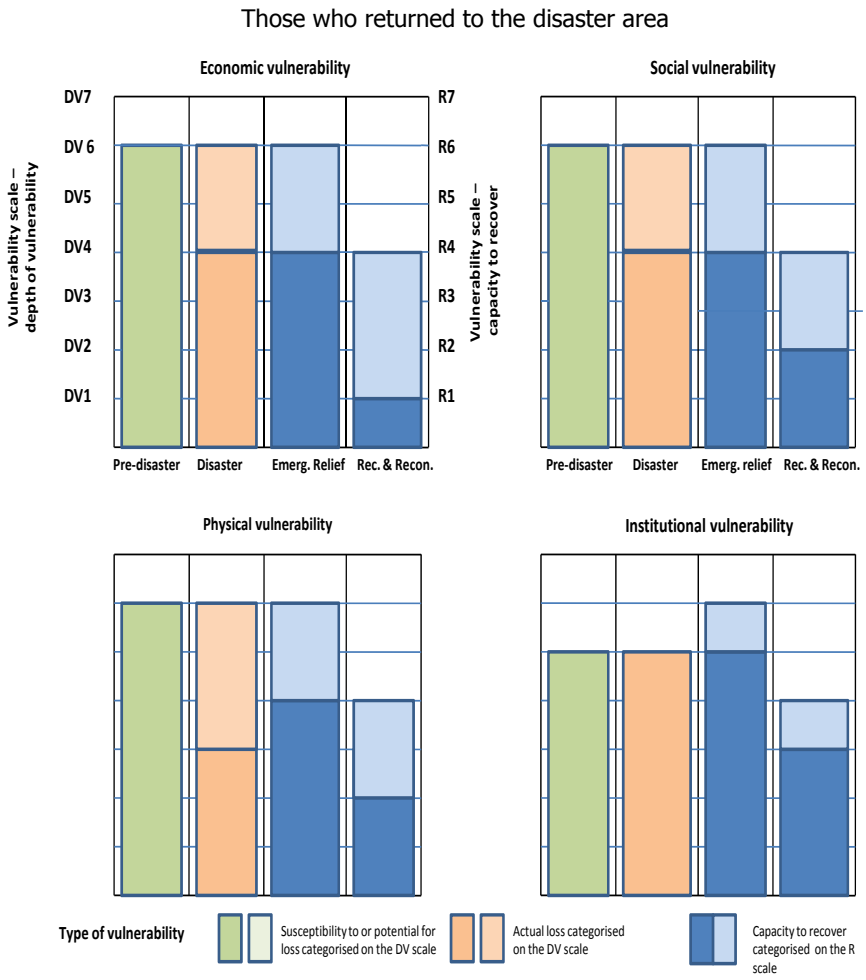


Figure 7: A multi-faceted vulnerability landscape for a) those who are disabled and b) those who returned to the disaster areas: St Bernard Parish, New Orleans, Katrina hurricane flood and oil contamination disaster, 2005 to 2010 (with the flood and oil contamination disaster viewed in isolation in time).

Developing a vulnerability landscape of the type summarized in Figure 6 is not without issues. The analysis which is referred to in this section 4.1.2 (and in Figure 6) focuses upon a single disaster event (i.e. the complex flood and oil spillage disaster), and in so doing demonstrates how financial vulnerability declines as the community progresses through the recovery and reconstruction process. However, this analysis is artificial in that it does not take into account vulnerability to the next future flood event. It does not take into account the vulnerability that arose as a result of the subsequent hurricane in September 2005 (Rita) (when breaches of levees had not been repaired) and also in August 2008 (Gustav) (when plans to upgrade the levees were only being discussed). Hurricane Rita led to some flooding of the already devastated Parish because of some levee overtopping and flooding through as then, unrepaired levee breaches. A disaster was only narrowly averted in hurricane Gustav as a result of emergency flood defense carried out by the USACE. St Bernard Parish remains less than 1 metre above sea level and future floods may well occur, leading to a continued financial vulnerability not factored in to Figure 6. During the emergency and relief phase the risk of a further disaster was in fact heightened until the levee breaches were resealed, and therefore financial vulnerability would have been higher than shown in Figure 6. In 2011, if implemented, the USACE's plans to improve the level of protection provided by the levees

will reduce the probability of a further event improving the resilience afforded to the community. Although the existing 100 year standard of protection is now recognized as being totally inadequate (US Congress, 2006, National Academies 2009, Southwell and von Winterfeldt, 2008), and probably less than 100 years due to land subsidence, an option being considered by USACE is improving the level of protection but only to the true, estimated 100 year standard (US Army Corps of Engineers, 2007). A second issue is that categorization is judgmental and qualitative and sometimes problematic because it may obscure significant variance in vulnerability within a population segment. By giving two category values to represent variance (for example, in Figures 6 and 7), an attempt has been made to address this issue by differentiating capacity to recover for some population segments where the variance is particularly significant. Even so the analysis is somewhat 'personal', dependent upon the particular data sources employed and might not be closely replicated by another analyst. It is possible to explore a more quantitative analysis but this has not so far been feasible.

Currently, the methodology does not capture some particular increases in vulnerability following Katrina, for some particular segments. For example, the flood and oil contamination disaster put families and individuals under severe stress. One outcome is that in St Bernard the rate of child abuse is reported to have increased by 150% on pre-Katrina levels, and the rate of elder abuse has increased by 335% compared with the pre-Katrina period (http://www.ccstb.org/).

In this methodology, susceptibility to loss is regarded as continuing through the post-disaster phases (and is represented in DRV), although in section 4.1.2 and in Figure 6 it is not considered because of the single-event focus. This assumption is relaxed in section 5.2.2 below which includes susceptibility to loss in the post-disaster phases within a multi-event focus. However, although completely excluded in this analysis, capacity to recover should also be regarded as present in both the pre-disaster and disaster phase because people possess the potential to recover before the event as well as manifesting this potential after the event.

Finally, it is sometimes difficult to identify the level of vulnerability on the vulnerability scales, and much depends on qualitatively weighing various key pieces of information.

d. Economic vulnerability development over time/ and the role of resilience

Baseline financial vulnerability

Median annual household incomes in St Bernard Parish are $35,939: considerably below the national median of $41,994 (http://www.epodunk.com/cgi-bin/genInfo.php?locIndex=3566). Pre-Katrina 13.1% of the population lived below the poverty line in the USA, many of these are over 61 years of age. Most had few financial reserves not locked up in their properties. Although some could not be described as financially deprived prior to the flood (some are described as middle class, others as working class), for many money was fairly or very tight.

Resilience strategies utilized by St Bernard parishioners

There were as many resilience strategies as individuals involved as victims in the disaster.Examples of the principal economic resilience strategies employed are given in Table 8, which also records resiliences influencing other facets of vulnerability.

Table 8: Examples of resilience strategies, with an emphasis on financial resilience, utilized by St Bernard parishioners in Katrina, Rita and Gustav hurricanes between 2005 and 2009

Disaster phase	***Economic***	***Social***	***Physical***	***Institutional***
Pre disaster	*Possession of flood insurance (25% ownership)* *Savings (but regarded as low through most of the community)* *Potential to evacuate self and family viewed here as income earners on basis of hurricane warnings and evacuation advisories/orders (2)* *Boarding up of homes to protect against wind damage, moved belongings, bought food and water* *A level of recovery capacity present in all of the above*	*A potentially high degree of recovery capacity present in this tight-knit community with, for example, several generations of families living adjacent to one another, faith groupings, ethnic groupings, working class solidarity etc.*	*A degree of resilience provided by the hurricane warning system, the city's evacuation plans and the levee flood protection system. Unfortunately the levee system was defeated, and the evacuation plans were seriously flawed for the most vulnerable, and so there were limitations to this physical resilience.* *Boarding up of properties to protect against wind damage.*	*Institutional failures and shortcomings were all waiting to be revealed by the disaster. Levels of resilience are of course present within this.*
Disaster	*Those evacuated stayed away from danger protecting their income earning potential from loss owing to death or injury*	*Some evacuees clustered en masse in the same evacuation location (e.g. Baton Rouge) to maintain social networks as far as possible (1)*	*Physical help given to people to evacuate, including transportation and road a pre-planned contraflow system to allow people to escape rather than get stuck in traffic congestion. Superdome designated as relief centre for those with special needs.*	*Institutional failures and shortcomings were all revealed by the disaster. Levels of resilience are of course present within this.*
Emergency relief	*Claims on flood insurance (up to 25% of population)* *Cost of temporary housing reduced as FEMA provides trailers (mobile homes)* *Some accessed church funds* *Accessed FEMA's Individual Assistance Program (Transitional Housing Assistance) to reclaim evacuation hotel expenses for those with damaged homes (3)* *Accessed rebuilding funds in kind (labour and materials) provided by voluntary sector – 430 private NGOs available with a desire to fund recovery efforts e.g. the St Bernard Project (4)*	*Community Centre set up to help rebuild social networks and to encourage resilience (5)* *Victims sought help from families in the form of social support*	*Fire and rescue, ambulance and police crews and engineers directed to the scene of the disaster reaching it about 6 days after the event.* *Some emergency repairs to damaged levees, but slow process.* *Trailers provided for those whose homes were uninhabitable.* *Evacuation centers made available in Houston and Baton Rouge and other locations.* *Physical help available with oil contamination clean up.* *Physical Help available to restore utilities.* *Physical help available to demolish severely*	*Institutional failures and shortcomings were all revealed by the disaster. Levels of resilience are of course present within this.* *Although slow the official emergency relief effort helped build resilience.*

	Some residents pursued and reached voluntary financial compensation settlements with Murphy. *Most residents of contaminated homes received clean up via Murphy* *Free legal aid taken advantage of by some residents* *Some sought and received financial aid from their families located elsewhere*		*damaged infrastructure such as schools, churches medical facilities.* *Decision to resettle in another largely hazard-free location.* *Decisions not to return to area until conditions are judged to be right to return.*	
Recovery and reconstruction	*Accessed rebuilding funds in kind (labor and materials) provided by voluntary sector– 430 private NGOs available with a desire to fund recovery efforts e.g. the St Bernard Project (4)* *Accessed via St Bernard local government agency, Federal/state grants for house demolition (from Federal Hazard Mitigation Grant Program, Community Block Development Grant* *Accessed financial compensation to property owners by Murphy following court case in which Murphy found negligent and ordered to compensate* *Volunteer organizations provided free food, and free clothes for low-income families, and also free access to telecommunications and internet (5)* *St Bernard Housing Recovery and Development Corporation formed to rebuild 1,045 units of affordable housing.*	*Community Centre set up to help rebuild social networks and to encourage resilience (5)* *Victims sought help from families in the form of social support*	*Physical help with property demolitions and rebuilding, and renewal of infrastructure.* *USACE assistance available to rebuild flood protection system.*	*Institutional failures and shortcomings were all revealed by the disaster. Levels of resilience are of course present within this.* *Although slow, the recovery and reconstruction has been aided by institutional mechanisms and processes, although often flawed.* *Learning is taking place as the lessons from the disaster are identified and acted upon.*

Notes: *(1)* www.cbsnews.com/stories/2008/09/01/eveningnews/main4405433.html *('Evacuees Weather The Storm En Masse')*
*(2) Emergency plans did not address the needs of those too sick or too poor to get out without help, and there was no system for removing them (*www.democraticunderground.com/discuss/duboard.php?az=view_all@address=132x2101441*)*
(3) www.nola.com/hurricane/index.ssf/2008/09/fema_draws_line_on_evacuees_ho.html
(4) www.stbernardproject.org
*(5) The Community Centre of St Bernard advertises itself as there to 'A Community Networking Resource', 'Nurturing the Resilient Community of St Bernard (*http://www.ccstb.org/

The pre-disaster period

Although the risk of flooding overtopping and breaching the levees protecting St Bernard Parish was significantly under-estimated by the local population (many apparently believing that the levees gave complete protection or that 'it could not happen here'), just prior to the event many evacuated drastically reducing their personal physical vulnerability, and with it the risk of injury and potential loss of ability to earn income. Believing in their resilience, a small minority chose to 'sit out the storm' and to ignore evacuation calls, but many of these died in the catastrophic flood because of the floodwater depths, and velocities, and the suddenness of levee breaches. The most vulnerable were the elderly and disabled in care homes, or living on their own. New Orlean's emergency plans anticipated that 100,000 people across the city would not evacuate given a catastrophic disaster because they would not have the means to do so, but they failed to plan and prepare adequately for this less-mobile population segment. Unfortunately, 34 residents of the St Rita care home located in St Bernard parish died in their beds, when staff evacuated, because of this institutional vulnerability and failure. Another circa 100 people in the parish died in a dockside warehouse where they had collected to be rescued because the flood arrived before the rescuers (www.foxnews.com/story/0,2933,168644,00.html).

Financial resilience can be significantly increased by possession of flood insurance. A significant proportion of the parish population had paid for flood insurance for many years, but by August 2005 many no longer had flood insurance because insurance companies rezoned St Bernard Parish out of the flood plain and told people that they no longer needed the insurance. At the time of the flood, only 25% possessed adequate flood insurance; 75% were either uninsured or inadequately insured (www.stbernardproject.org). For most, all savings were tied up in their homes. Warnings can also provide a degree of resilience. Based on hurricane warnings, many home and business owners boarded up their properties prior to the hurricane to reduce the chance of property damage. However, such actions are designed to prevent wind damage rather than flood damage and proved to be an ineffective physical resilience measure.

The disaster period

Evacuees sat out the flood disaster in another location, and as many as possible sought to increase their resilience by moving well away from the eye of the hurricane. Many evacuated to locations out of Louisiana, for example in Houston and Dallas in Texas. Others evacuated to other parts of Louisiana, although thousands also evacuated to another address in New Orleans reducing their vulnerability less. For many the disaster period was the beginning of a long period (i.e. 4 months to several years) spent at an alternative address and a significant proportion of these subsequently reported an increase in their housing costs as a result. Financial deprivation and vulnerabilities increased for many as most members of the local population were comparatively less well-off than the average American.

4.2 Dynamics of disaster losses as reflections of vulnerability fluctuations in time- Determinant factors

4.2.1. Dynamics of losses in Wildfires in Australia

a. General information

Wildfires present specific risks to life and property when they reach the interface between wildland area and urban area. In terms of property loss, and hence vulnerability, the potential is greatest at the urban – wildland interface.

Already in 1968, Vines stated that "*Australia's fire problem really concerns the very large fire which burns for days on end, and involves some million acres before being put out by rain.*" "*…in addition, on many occasions, people are killed and houses burnt down*."

The issues surrounding house loss are complex and include several aspects linked to mechanisms of ignition and propagation of wildfire in urban areas (Blanchi et al, 2006). The severity of the weather, topography and fuel load determine at great extent the intensity of these attack mechanisms. In a historical perspective Figure 8 (McAneney et al, 2009) shows the annual aggregate numbers of buildings destroyed in Australia by wildfires since 1926.

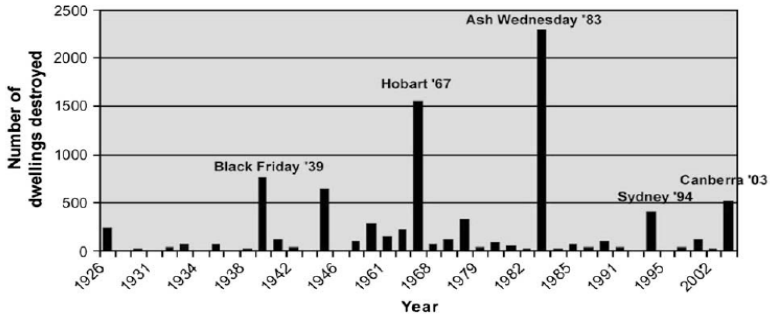


Figure 8: Annual number of dwellings lost to bushfires since 1926

The average number of homes destroyed annually is 84 and the historical record shows very clearly that most building damage occurs during infrequent extreme events such as in the case of the iconic forest fires of 1983. Furthermore, the actual loss in a wildfire is a random variable that depends upon a host of variables including whether or not it intersects a populated area, the disposition of threatened houses and human intervention.

By analyzing the probability over time of dwellings losses (Table 9) one can observe that the likelihood of losing homes to a wildfire has remained remarkably stable over the last century with some building destruction expected in about 55% of years. This same stability was also exhibited for the bigger events with an annual probability of losing more than 25 or 100 homes in a single week remaining around 40% and 20% respectively (McAneney et al., 2009).

Start year	1900	1926	1939	1967	1983	1990
Annual probability of a non-zero loss	56%	53%	48%	57%	57%	57%
Annual probability of losing >25 homes in 1 week	39%	40%	42%	41%	38%	36%
Annual probability of losing >100 homes in 1 week	18%	19%	22%	19%	19%	21%

Table 9: National bushfire building loss probabilities calculated between the start year and 2003. The first row gives the frequency of any (non-zero) loss while the second and third includes only those events that have resulted in more than 25 or 100 homes destroyed within a single week.

Also of great usefulness is to investigate the spatial pattern of the most vulnerable households across the major Australian cities. About 6% of households were fund to be within 100 m of woodland and thus the most at-risk addresses. After adjusting for duplicates in the address database and for regions around major cities, a realistic upper bound on the national number of most at-risk addresses of about 550,000 was found. The other four groups are in intervals out to and beyond 700 m from woodland, the maximum extent to which we have seen building loss in Australia (Chen and McAneney, 2004).

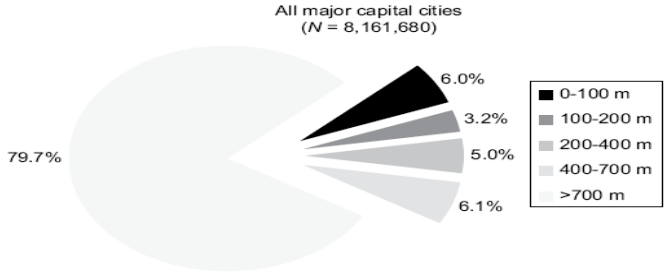


Figure 9: Percentage of addresses by distance category from large areas of bushland

In addition building design, town planning and human activity significantly influence the risk of loss. In this light a total 1871 houses have been surveyed and the damages assessed over three major wildfires events in Australia, namely: The Otway fire in 1983, Sydney fire in 1994 and finally the Canberra fire of 2003. Each survey used a common approach, which has undergone a process of continual improvement since 1983(Blanchi et al, 2006).

Three determinant mechanisms of fire attack in urban-interfaces could be identified, namely: Embers, or fire brands, radian heat and flame (Blanchi et al, 2006).

Of the 68 damaged houses examinated, 52 were clearly identified as being ignited by embers in absence of significant flame and radiation impact from continuous forest fuels. The cause of ignition of the remaining 16 (24%) houses was less clear in many cases because the primary attack point was lost due to substantial flame spread around the ignition point (Ramsey and McArthur, 1995). The combination of embers and damage caused by urban fuels (adjacent structures and fences) were reported to be the main source of house ignition.

The 2003 survey (Blanchi et al, 2006) identified a high percentage (>90%) of houses as being attacked by embers only and a combined effect of radiant heat and embers. The houses didn't show any evidence of direct ignition from the fire front itself. Vegetation between the fire front and the first row of houses in the survey area did show signs of convective heat damage. While the convective heat from the fire front was not sufficient to cause damage to structures, it is likely to have assisted in increasing the likelihood of ignition by embers. The damage was mainly the results of ember attack or the results of surrounding objects leading to house ignition. The impact of radiant heat on a house not only supports the ignition of flammable material, but may also create openings by causing broken windows, which facilitates the entry of embers into the structure (Blanchi et al, 2006).

b. Determinant factors of property loss

In theory the growth from 4 millions to 20 millions in population during the last century may suggest that the pressure of housing in the wildland-urban interface increased. On the other hand the annual probability of losses, as seen before in Table 9, remained particularly stable. This means that there must be other underlying factors contributing the spatial and temporal vulnerability. One possible explanation is that the resources into fire fighting and education have increased over time exactly in balance with the presumably increasing risk (McAneney et al, 2009).

A more credible theory seems to be the argument that large losses occur rarely and under extreme weather conditions when fires get out of control and converge to create so-called mega-fires. In fact, for the last 75 years five single events have accounted for the majority of losses. A determinant factor seems to be the existence of a particular forest fire area

threshold after which there is very little that can be done to stop the wildfire until it either runs out of fuel or weather conditions change (McAneney et al, 2009). In this perspective the global climate change may add a further level of uncertainty to the above picture in the future, both by increasing the likelihood of conditions that lead to wildfires (Pitman et al., 2007) and through unknown influences on the El Niño – Southern Oscillation cycle that affects Australian climate and weather (Powers et al., 1999).

Climatic change will affect fire frequency. Many studies using general circulation models (GCMs) have anticipated significant increases in fire weather and fire danger over large sections of Australia, Europe, North America, and Russia (Stocks et al., 1998).

The existence of these extreme events may be on of the main determinants of vulnerability over time; nevertheless there are other more local determinants for property loss. For example the Australasian Fire and Emergency Service Authorities Council (AFAC) position states that the most important aspect of preparation is the creation and maintenance of 'defendable space', this is a space around the house in which fuels are reduced to protect against ember attack and radiant heat.

Research on building ignition during bushfires supports the assertion that well-prepared houses can be successfully defended and can provide safe refuge during the main passage of the fire front (Leonard and McArthur, 1999). It shows that wind-blown embers (rather than direct flame contact or radiant heat) are the most common source of house ignition before, during and after the main passage of the fire front (Leonard, 2003). Crucially, residents are advised to prepare their properties for bushfires regardless of their intention to stay and defend or leave early, in order to ensure the safety of firefighters who may be defending the property (Tibbits and Whittaker, 2009).

c. Human vulnerability

The historical evolution of human losses in major fire events that toke place in the district of Victoria is showed in Table 10 (Tibbits and Whittaker, 2007). The fatalities numbers reveal a sharp decrease over time for the selected extreme events of similar magnitude. For instances, while the area affected by the extreme fire events of 1939 and 2003 reveals to be similar, the number of fatalities could not be more distinct.

Table 10: Life and property losses in major Victorian bushfires

Losses	1939	1983	2003
Fatalities	71	47	1
Houses destroyed	650	2000 +	41
Stock losses	N/A	27,000	11,160
Area burnt	1.5 million ha	200,000 ha	1.12 million ha

Based on the evidence that nearly all wildfire related deaths occur out in the open when people are exposed to high levels of radiant heat and smoke, often during evacuation (Haynes et al., 2008), Australian fire authorities promoted over time the policy to encourage homeowners to be either prepared to defend their homes or evacuate early, well before the fire front approaches (Tibbits et al., 2007). This is a unique approach to community safety for wildfires when compared with international approaches, where mass evacuation is the norm (McAneney et al, 2009). The decision of leaving early or stay and defend, determine therefore much of the human vulnerability to wildfires in the Australian context.

For example, late evacuations are typically triggered by the appearance of flames and/or heavy smoke in the vicinity of a person's home. By this late stage, it is likely that driving a vehicle will have become very difficult, with flames, smoke, strong winds, fallen trees and

the urgency of the situation increasing the likelihood that a driver will become disoriented or lose control of the vehicle. An analysis of recorded bushfire fatalities in Australia found that 78% of all deaths occurred outside or in an indefensible space (Tibbits et al., 2007). The available evidence that "houses protect people and people protect houses" is strong, at least in the Australian context. In particular, the data demonstrate the danger of last minute evacuations (Handmer and Tibbits 2005)

d. Determinant factors for "stay and defend" or "leave early"

In the Australian context, the determinant factors for human vulnerability lay on the way persons base their decisions of staying and defend or leaving early. A study conducted in the district of Victoria provides insights on the factors upon which persons base their decisions under the threat of a wildfire. On the whole, the study participants demonstrated a high level of understanding of *'prepare, stay and defend*', but were less certain of the meaning of '*leave early*', it was pointed that this message is not well understood and requires further clarification (Tibbits and Whittaker, 2007). On the other hand, many of those who decide to stay and defend are consciously or unconsciously retaining late evacuation as a last-minute option, despite widespread recognition of the dangers of such a strategy.

Decisions to stay and defend or leave early are influenced by a range of factors. People's confidence in the survivability of their house and their own physical and mental ability to stay to defend it is fundamentally important. Other considerations, however, such as responsibilities for vulnerable household members, level of commitment to property, work and emergency-related responsibilities are also factored into decisions and planning. Age, mobility, reliance on public transport, responsibility for young children and remoteness of property are also pointed as factors that influence the action of leaving early (Tibbits and Whittaker, 2007). Table 11 resumes the findings of the main factors influencing the decisions of the population facing a wildfire.

Table 11: Factors that influenced participants' decisions to stay and defend or leave early during the 2003 fires (Tibbits and Whittaker, 2007)

Factors
Confidence that their house is defendable
Confidence in their physical and mental capacity to stay and defend
Number of people available to stay and defend
Responsibility for 'vulnerable' household members (e.g. young children)
Level of preparation and access to a reliable water supply
Activities and visibility of the Country Fire Authority (CFA)
Preparedness and attendance of surrounding properties
Family and work commitments
Level of commitment to and investment in property (e.g. rental property versus family farm)
Responsibility for livestock and pets
Location of property (e.g. distance from/accessibility of refuge points)

4.2.2 Loss and vulnerability sequences in St Bernard Parish, the Katrina flood and oil contamination events of 2005

For a general description of the disaster see section 6.1.2 and Del. 2.1.

a. Types of loss and vulnerability

Figure 10 presents a conceptualization of generic types of flood loss (Parker, 1999). This typology distinguishes direct from indirect flood losses. Direct losses precede indirect losses in time. Direct losses are those caused by the physical contact of floodwater with property susceptible to damage, and susceptibility to this type of loss is a key physical and economic vulnerability. Indirect losses are those caused as a consequence of direct damage. They comprise disruption and business interruption costs and the additional costs of deploying the emergency services during, as well as in advance of, a flood event. Pre-flood evacuation costs are included here, as are post-flood evacuation costs. A third category of losses comprises human and social capital losses, including loss of human lives, homelessness, disrupted and blighted lives, anxiety, stress and extra ill-health, as well as the other consequences of flooding shown in Figure 10. Susceptibility to this type of loss is a key social vulnerability. A fourth category of loss is environmental loss. For example, in the Katrina flood surge which severely damaged St Bernard parish, important wetlands were also destroyed. These wetlands form a natural barrier between the flood levees and the sea and are important, not only as marginal tidal habitats, but as natural defenses against flood surge. It has been customary in the UK to distinguish between tangible and intangible losses on the basis of whether or not monetary values can be attached to them, but this is not a particularly important issue here.

b. Propagation and expansion of flood losses through time

It is clear that flood losses propagate and expand through time. This is captured in Figure 10 by the concepts of primary, secondary and tertiary losses which are similar to 'ripple effects' and which describe the sequential effects of a flood. For example, serious and/or prolonged business disruption may lead to business bankruptcies. This was a severe outcome in the case of the flood in New Orleans (mainly because businesses lost both employees and customers because of the major and prolonged evacuation of the city). Infrastructure loss (e.g. loss of water supplies, loss of communications, road and rail traffic disruption) can also lead to secondary impacts. The effect of how serious a flood may be is captured in the concept of the 'multiplier effect' which estimates the effect of a loss as it ripples through an economy. For example, when a factory is closed down as a result of a flood, and employees are laid off work, the purchasing power of employees declines because they have less income to spend and this has a knock-on effect on other businesses which depend on their purchasing power. In the Katrina hurricane and flood, the damage to oil extraction, refining and production and shipping was such that the negative effects were felt through the whole US economy reducing economic growth by about a percentage point (Robin-McCaskill, 2006).

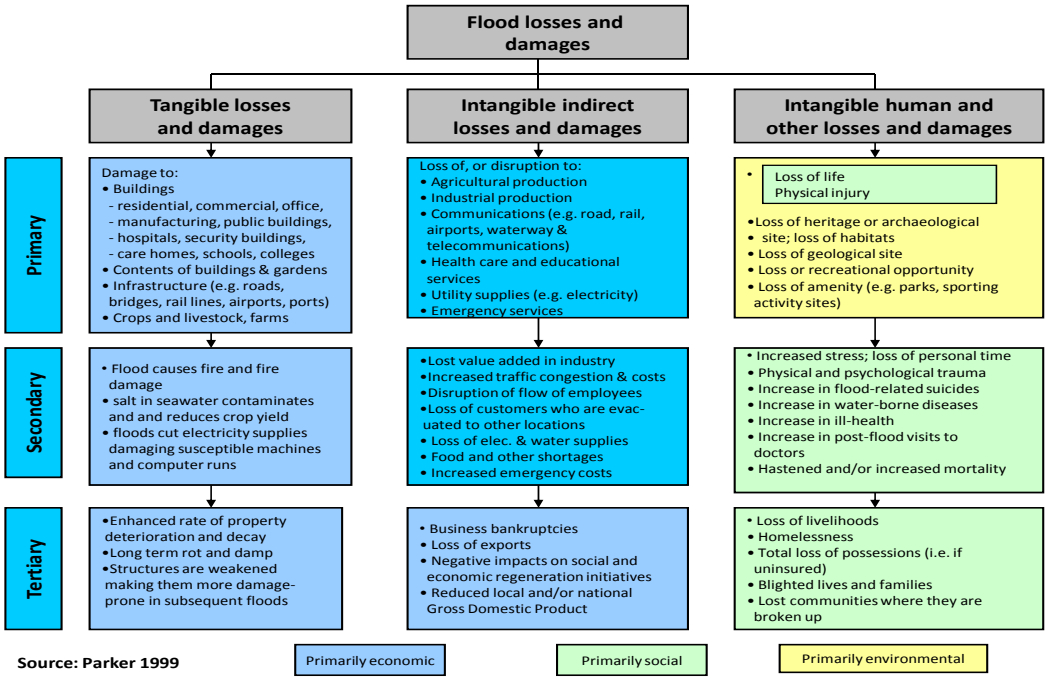


Figure 10: A typology of flood losses

Flood losses propagate through time partly because the negative effect of flooding on properties sometimes takes time to emerge. For example, timber flooring which is flooded and not dried out properly afterwards will gradually rot (over weeks and months) and will subsequently need replacing. The salt from tidal water is difficult to remove from brickwork and can cause damp for many years after the event. Flood losses also propagate through time mainly as the indirect (including secondary and tertiary) effects of disasters. The longer the recovery period, the more these losses will expand within the area directly affected by the flood, and also beyond it because of the multiplier effect. Thus, in Figure 11 a cumulative loss curve would be shown as a continuously climbing one.

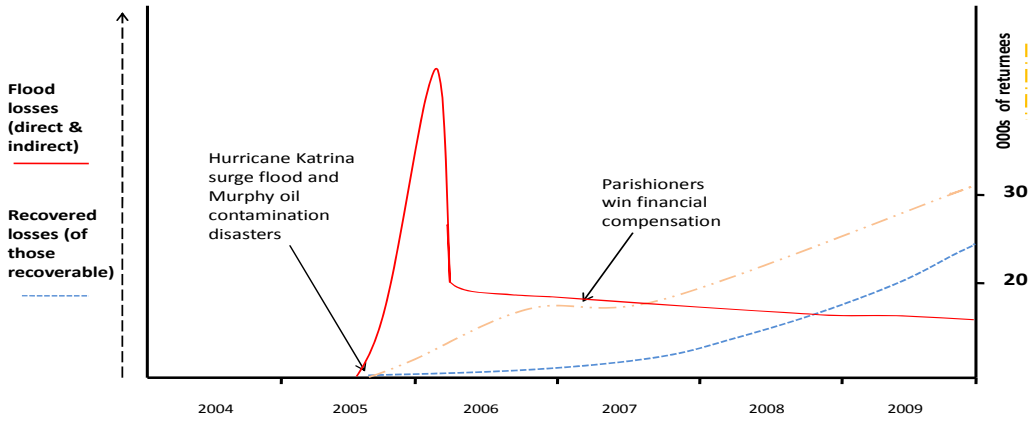


Figure 11: Conjectured trajectories of losses and recovered losses, and actual trajectories of returnees in St Bernard parish over time

Figure 12 gives examples of different types of loss according to disaster phase. Emergency service costs are defined here as indirect costs or losses. They are technically the marginal (i.e. additional) costs of deploying these services in an event. Costs, which are equivalent to losses, are usually incurred in the immediate run up to a disaster (i.e. in the latter stages of the pre-disaster phase) because of the need to deploy emergency services and to evacuate people. Unless a disaster is completely unexpected, business disruption begins in advance of a disaster as people begin to evacuate and businesses close down. Direct damages are the predominant form of loss in the disaster phase and these include direct damage to people (e.g. loss of life) and to all forms of property, although some indirect losses will also be incurred (i.e. emergency service costs). In the two post-disaster stages the predominant loss type is indirect although, as pointed out above, some direct losses may only emerge during the emergency relief or even the recovery and reconstruction phases.

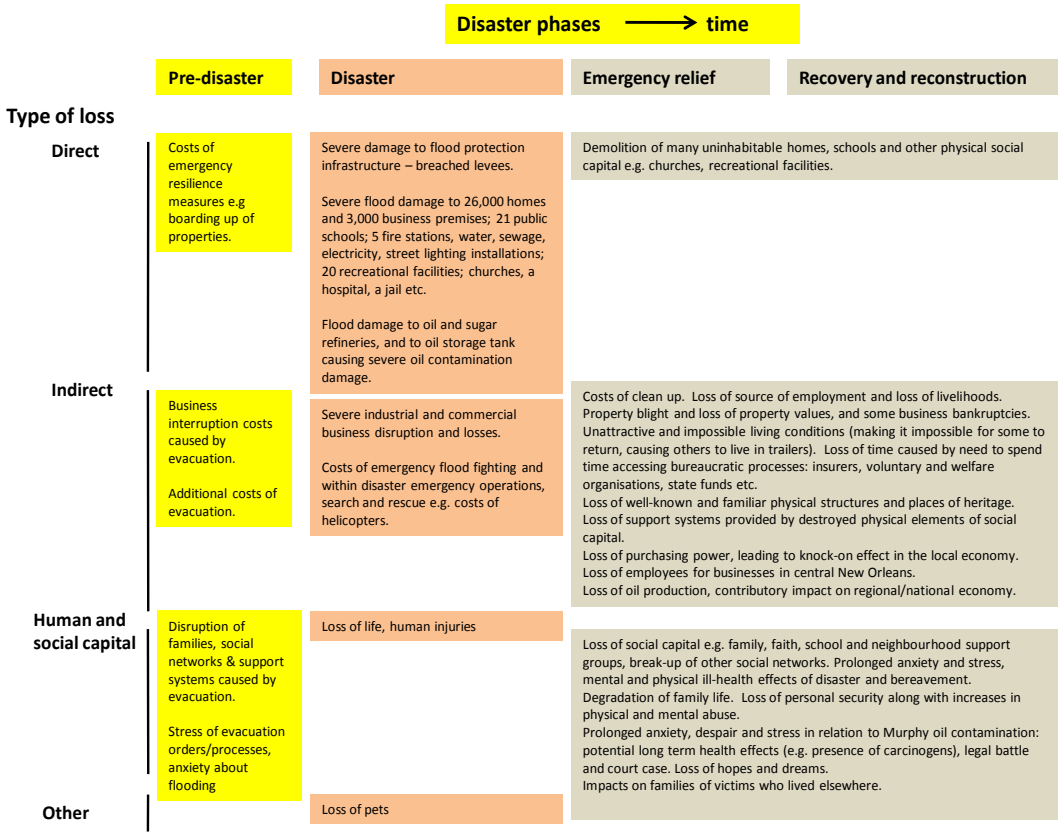


Figure 12: Examples of flood loss categorized by type and disaster phase

c. Propagation of recovery from losses

St Bernard parish was so heavily devastated by the tidal surge in August 2005 that recovery of losses is taking and will take a long time (in this respect the disaster is similar to a major damaging earthquake). In general, direct losses need to be recovered in order for indirect losses to be halted and where possible recovered. In much less serious floods, where a commercial area is, say, flooded for up to several weeks, processes of deferral allow much lost trade and business to be recovered over time. People may delay/defer purchases especially for non-perishable goods, making these purchases several weeks later. Transferal of business to flood-free outlets may also take place, especially for perishable items. But in severe floods where the recovery time is long, nearly all trade and business tends to be transferred to flood-free commercial centers which may gain trade as the flooded area loses trade, thereby creating winners and losers. In the case of St Bernard parish most of the

flood victim's purchasing power was transferred to the areas to which they were evacuated, and only returned to St Bernard parish with the returnees, delaying business recovery in St Bernard. In this regard, business recovery is more or less in direct proportion to the pace and number of returnees. The loss recovery curve for St Bernard parish is likely to resemble a very flat one because of these loss recovery patterns (Figure 11). Unrecoverable losses include loss of life. Flood losses climb at first to reflect the enormous direct damage and then decline to a level which reflects on-going indirect loss which gradually reduces over time. The effect of the court judgment, which directed financial compensation, on the actual rate of return of parishioners can be observed.

5. Patterns of vulnerability evolution over successive disaster cycles

Vulnerability undergoes fundamental changes when the carrying agency (e.g. a building, an ecosystem, a household, a community, a territory) experiences more than one disaster event i.e. e series of events. Each disaster cycle resets the vulnerability status of the stricken system so that this system enters the following cycle (crisis) from a different starting vulnerability point. The vulnerability changes that correspond to the influence of each cycle depend on:

- The losses caused;
- The response / coping capacities activated during the emergency and recovery periods;
- The changes in risk vulnerability perception (awareness) induced by the event and its repercussions

The fact that after each disaster cycle the hit system remains with certain non- recovered losses means that the system will have to face the next event from a deteriorated and hence more vulnerable condition. On the other hand, some aspects of the system may have become more robust of latent coping/ response/ adaptive capacities after the first event because of the activation and their curing effects on initial and pertaining for long predisaster vulnerabilities. In this respect, it seems that there is an underlying fundamental difference between social and ecological systems.

The chapter includes two sub-chapters; Sub- chapter 5.1 deals with the impact of successive disaster cycles on physical, social, economic, institutional, technosystem vulnerability while Sub- chapter 5.2 deals with the more complex territorial and ecohuman systems' vulnerability.

5.1 The impact of successive disaster cycles on physical, social, economic, institutional, techno-systems' vulnerability – Determinant factors

5.1.1 Successive impact of earthquake events: the El Salvador 2001 crises

The earthquakes that hit successively El Salvador in 2001 (January 13th - Mag. 7.4; February 13th – Mag. 6.1) provide a good illustration of the evolution of the distinct vulnerability facets over time (AFPS, 2001), within a disaster cycle and also between disaster events. This case study has already been detailed in Deliverable 2.1.2 (WP2), main facts will be taken up again and analysis diagrams will be presented within a time approach perspective.

In San Salvador (capital of El Salvador), the relatively good performances observed for lifelines and engineering structures (*systemic vulnerability*) during the two successive 2001 earthquakes can be partly attributed to the past disastrous (natural and human) experiences El Salvador has faced since the 80s' (e.g. the 1980-1992 civil war, the 1986 earthquake, Mitch hurricane in 1998).

For instance, the 1986 earthquake crisis, which resulted in massive destructions, has highlighted the key role of anti-seismic design (*physical vulnerability*) with regards to system functionalities (e.g. lifelines, services, infrastructure elements). This event has led to a vast reconstruction program based on existing anti-seismic design codes, which has proved to be efficient during the 2001 crisis (JSCE, 2001).

Apart from design considerations, the short intervals between past disaster cycles has permitted a direct transmission of experiences and knowledge between generations (e.g. parents to children). Longer time periods between events would probably have led to a decrease of vigilance over time.

All these elements (cf. Fig. 13) have lead to an increased *coping capacity* and preparedness to emergency situations (e.g. widespread use of emergency generators, etc.).

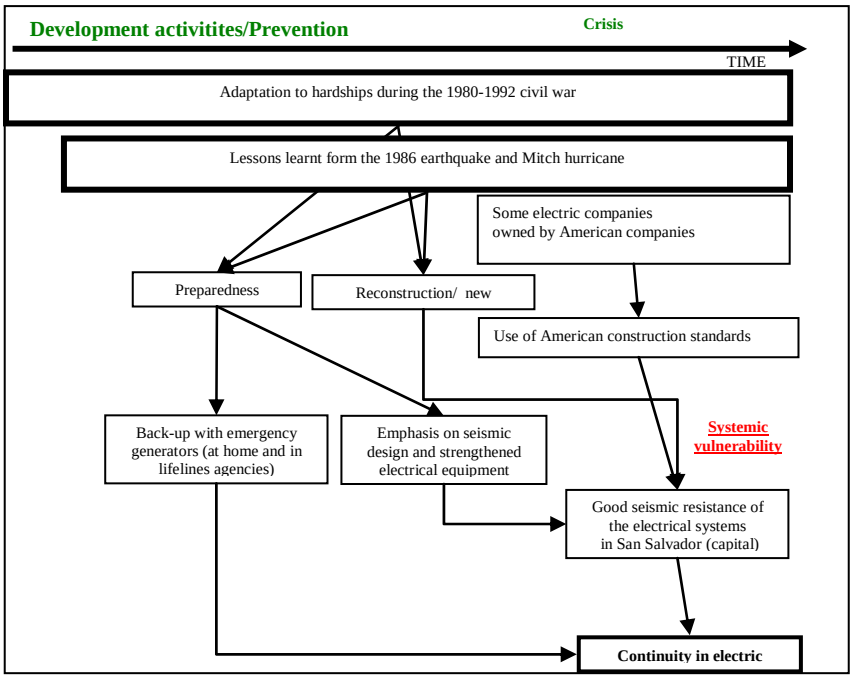


Figure 13: Decrease of internal systemic vulnerability of electric lifelines in San Salvador due to past experiences and improvement in resistance (cause-effect relationship) (past exposure → increased Coping Capacity + reduction of physical vulnerability → reduction of systemic vulnerability)

In the following, we will try to outline the impact of time aspects with regards to the 2001 crisis.

Systemic vulnerability:

Destruction and/or failures related to the electric network (e.g. electric lines, generating plants in rural areas), combined with a lack of formal emergency response and plans (*institutional vulnerability*) have resulted in total electric outage in central and eastern regions for at least 3 days (Lund and Sepponen, 2002).

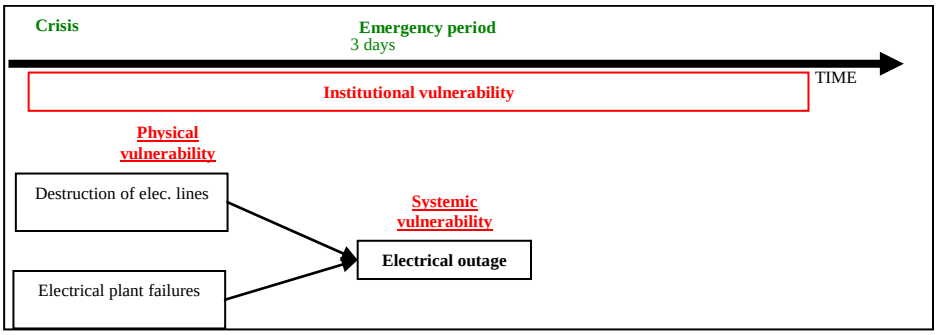


Figure 14: Systemic vulnerability of electric network in the emergency phase

Severe damages, which occurred after the second earthquake on key water facilities (e.g. Chacahuatal treatment plant in the San Vicente area), have led to stopping water supply in some areas, increasing the dependency of populations on the delivery of drinkable water by trucks (Lund and Sepponen, 2002). Consequences of disruptions in water distribution resulted also in health issues (*social vulnerability*). In this case, the short time interval between consecutive events made the in-between recovery of water systems impossible (*Incapacity to recover*).

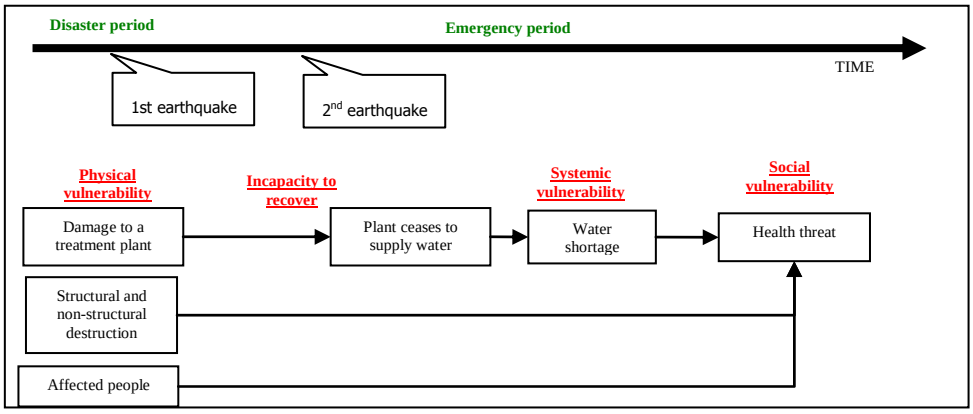


Figure 15: Physical vulnerability + incapacity to recover in successive events ➔ systemic and social vulnerability

Damages to the transport networks resulted in long term consequences (weeks to months), as disruptions in the systemic functionalities were combined to economic losses:

- The indirect costs due to the obstructions and diversions related to the main Salvadoran roads and highways (e.g. the Panamerican Highway) have been estimated to account for more than 80% of the total estimated cost of damages to transport infrastructures *(economic vulnerability*). In this case, loss of functionalities for months has affected not only the national sectors, but also the regional economy (e.g. the Panamerican Highway is a major road for most of Salvadoran and South American passengers and goods traffic).
- Due to inaccessibility of some rural areas for emergency and repair services, the time period of dysfunction was increased (*external systemic vulnerability*).

Institutional vulnerability:

This example demonstrates also that the institutional vulnerability behaves like a catalyst of physical and systemic vulnerabilities through time (e.g. increase in duration of system disruptions). For instance, the functionality loss of the Salvadoran healthcare system was mostly due to lifelines disruptions (*external systemic vulnerability*) and deficit in trained staff (*human capital*) (Boroschek, 2004), in addition to a pre-existing lack of *redundancy* (e.g. centralized specialized services). One year after the events, 28% of the existing beds were

still in field hospitals, and some medical services in the country could not perform appropriately (e.g. oncology) (Boroschek, 2004).

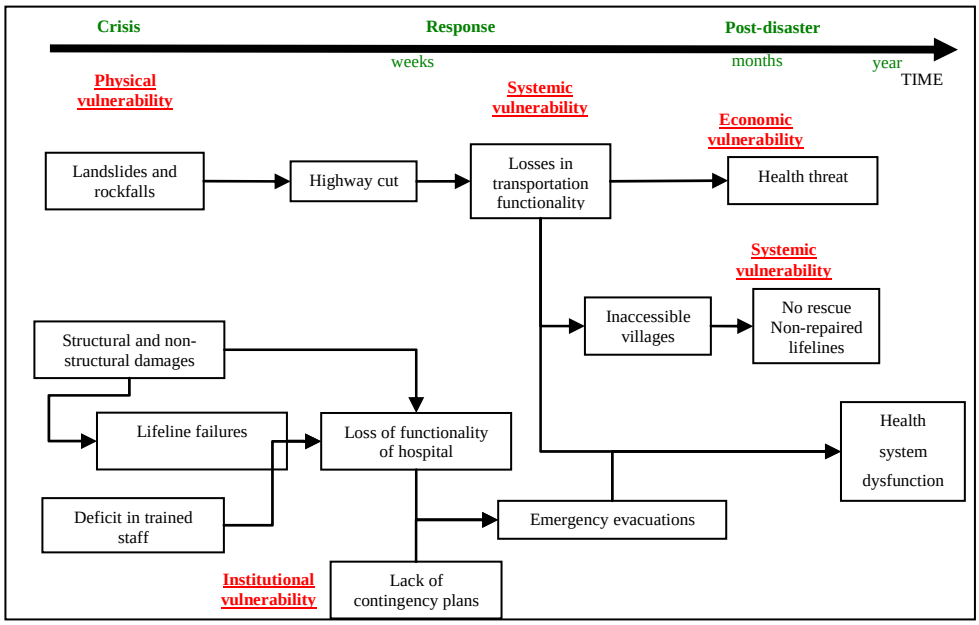


Figure 16: Long-term consequences of systemic vulnerabilities

Seasonal vulnerability:

Finally, another important fact to consider is the time of occurrence of disastrous events: in the case of El Salvador, as the seismic crisis hit during the coffee harvest period, many coffee pickers were killed due to the numerous landslides, which were induced on the slopes of volcanoes used for coffee cultivation (*physical vulnerability*) (Bommer *et al.*, 2002).

5.1.2 Successive impact of hydro-meteorological and earthquake events: the French West Indies 2004 crises

a. General description

Among the past disasters, the crisis that hit the Guadeloupe archipelago (Western Indies) in a short time period (November 2004), including floods, landslides and a destructive earthquake (Magnitude 6.3), provide a good illustration of the evolution of the vulnerability facets and institutional tools with respect to time (AFPS, 2004). This case study has already been detailed in Deliverable 2.1.3 (WP2).

In 2004, the Guadeloupe archipelago was struck by a tropical storm (Jeanne, September 13-14) and intensive rainfalls (November 18), causing historic floods and numerous landslides on the main Guadeloupe Island (Basse-Terre, Grande-Terre). These hydro-meteorological events were followed by the 'Les Saintes' earthquake (November 21), which occurred in the Southern part of the Guadeloupe archipelago, and resulting in more damages in Les Saintes Island and Basse-Terre (Guadeloupe), mainly due to ground instabilities.

b. Increase in environmental & physical vulnerability

The time interval between the hydro-meteorological and seismic events in a context of institutional vulnerability was a critical and determinant factor for environmental and physical

vulnerability increase, as most structural and non structural damages were caused by the reactivation of unstable zones already saturated with water due to the intense rainfalls a few days before. The short time interval made it impossible to identify these dangerous areas and to take proper counter-measures in case of further physical stress (e.g. more rainfalls, earthquake). An unknown number of ground instabilities were triggered by the first event, but without major consequences, and further enhanced during the second event, causing then more destructive landslides (slope failures, rockfalls, etc.).

c. Increase in systemic and economic vulnerability

The communication and transportation networks (roads, etc.) are highly exposed to natural threats in these territories. The 2004 crisis has occurred just after a main regional financial investment period (from 2002 to 2004), during which some large works were financed to arrange and develop road networks and tourist sites. For instance, in the West part of Guadeloupe, there is only one major road (RN1, four tracks), which concentrates most of the daily traffic (freight and numerous home-to-work travels) between Pointe-à-Pitre (North) and Basse-Terre (South). Another small road exists, but it is unsuitable for trucks and takes however much longer time. Due to the November 2004 crisis, the RN1 road was totally cut for a few days after the intense rainfalls and resulting landslides. Then, two tracks out of four have remained closed for six months after the earthquake.

Moreover, as the local economic incomes are essentially based on tourism and agriculture/agribusiness, the long-term disruptions for a number of strategic roads (*systemic vulnerability*) and difficult access and/or closure to highly tourist sites, in addition to a lack of suitable alternative roads (*coping capacity*), have increased the economic vulnerability of the region.

For instance, the last part of the only road leading to the top of the Soufrière Volcano (located in the Guadeloupe National Park, with about 300,000 visitors per year) is cut since November 2004 and the main tourist parking is also closed since 2004, preventing tourist buses to park at a reasonable walking distance from the top. Moreover, this road is also the only access to carry out maintenance works on two main transmitting antennas used for the whole Guadeloupe archipelago: they are to be carried out by helicopter now. The economic costs required for the rehabilitation of the access road is too high for the Region and no work program has been launched yet.

Another example is the second Carbet Waterfalls site (about 500,000 visitors per year), which is classified as highly dangerous since the earthquake due to potential rockfalls and even cliff collapse, and which access is strictly forbidden since the 2004 crisis.

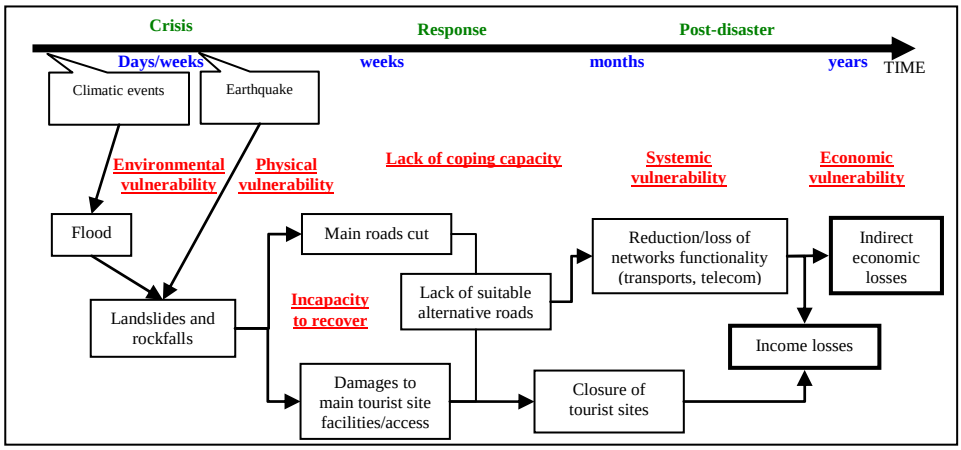


Figure 17: Environmental & physical vulnerabilities + incapacity to recover ➔ long-term systemic & economic vulnerability increase

The time required for institutional response to the crisis was also a crucial factor for physical vulnerability increase: since cut roads were closed for safety reasons for a relatively long period, many people decided to break the security barrier and travel at their own risk *(moving socio-economic vulnerability ➔ physical vulnerability)*.

d. Evolution of resilience over time

In the West Indian society, where superstitions, mysticism, religious and fatalist beliefs are prevailing, the common attitude is generally passivity and wait-and-see (*social vulnerability*). There is also a predominant apology of self resourcefulness, which may be a factor of resilience, but may also enhance physical vulnerability, as people do not understand the need to prepare between successive events: 81% of investigated people in Guadeloupe had taken no specific dispositions before the 2004 earthquake and 85% admitted having taken no new dispositions after it.

Another point is the chronic local institutional failure to face catastrophic events in this region, mainly due to a lack of coordination between services in charge of crisis management. However, a spontaneous social control mechanism generally appears to take over the institutional incapacity: emergence of local leaders and community organization (solidarity), to overcome the social disruption due to the disaster and for a limited time period.

e. Evolution of risk perception over time

Although Guadeloupe was hit by strong earthquakes in the past (e.g. Guadeloupe 1843: more than 3000 deaths, main city of Pointe-à-Pitre destroyed; Martinique 1839: at least 300 deaths, maybe around 3000 according to a reviewer, main city of Fort-de-France destroyed), some surveys performed after the 1999 Martinique and 2004 Guadeloupe earthquakes underline public unawareness of seismic risk perception due to the infrequency of occurrence of large seismic events (e.g. CETE, 2005). The surveys showed that risk perception and awareness within the local population and authorities is good regarding seasonal climatic events, the only problem coming possibly from the unawareness of tourists in this case. Hence, people are generally well-prepared for such recurrent events (e.g. emergency kits kept in safety place in houses, such as in hard basement). On the contrary, a large public is not aware of being in a seismic zone. Respondents to the 2004 survey did not know what an aftershock was (about 25000 aftershocks occurred for one year after the main shock of November 2004). A statistic treatment has been performed recently in Martinique (Leone, 2007), to quantify the collective memory of historical seismicity for a given time interval,

1950-1997 in this case (see Fig. 18). The results for earthquakes of magnitude superior or equal to 5, show that very few events (essentially 3: 1969, 1970, 1990) can be cited and dated correctly *(large time interval between seismic events ➔ decrease of public and institutional awareness ➔ increase of vulnerability)*.

Constructions also reflect this risk perception, as "self-made" houses are preferably built in order to resist frequent tropical storms and avoid consecutive effects (e.g. flooding, strong winds), but increasing thus physical vulnerability to earthquakes and/or landslides (e.g. building on high grounds or on pilotis, near slopes or cliffs).

Moreover, surveys conducted in the region after Lenny hurricane (1999) have shown that due to historical and political reasons, there is a lack of public perception of the reality of cyclonic and seismic risks for the whole West Indian island Arc. This regional perception is almost confined within the scientific community. For instance, some important recent earthquakes from Martinique are generally not cited by people from Guadeloupe.

Another point is that quasi-simultaneous events (intense rainfalls and earthquake) led to a major misunderstanding and bad risk perception: people are convinced that important rainfalls are signs that herald an earthquake. Future prevention campaigns will have to fight hard against this confusion.

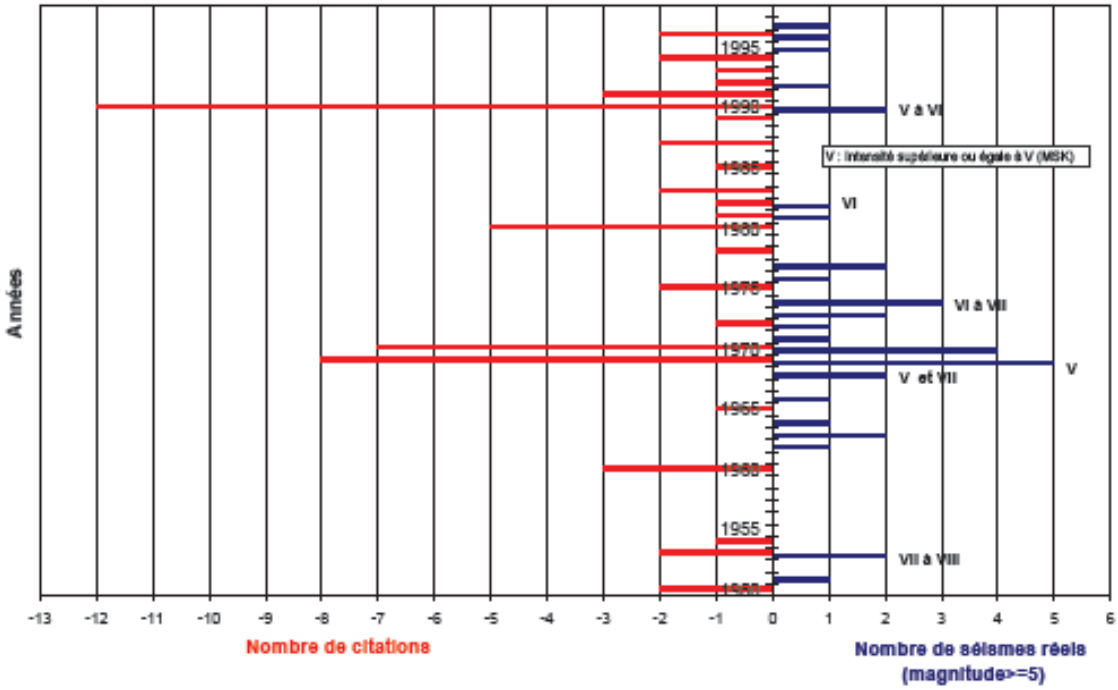


Figure 18: Comparison of real earthquake events in Martinique (blue) and number of citations by the population (red) for the 1950-1997 period (after Leone, 2007)

f. Institutional response and evolution over time

Martinique and Guadeloupe departments have been historically strongly exposed to various natural threats, and they rank at the maximum seismic risk level within the national classification (official decree in 1999). However, the French institutional recognition came only in 1990, just after Hugo cyclone, which struck Guadeloupe in November 1989.

Although seismic hazard factors are well known and have remained constant over time, the lack of regulation and control prevailing up to 1999, could lead to heavy losses in the future. Indeed, allowing to the conclusions drawn in the scientific report of the GEMITIS study performed in Guadeloupe by brgm in 1999, should an earthquake comparable to the 1839 or 1843 one occur (this time period corresponds to a probable return period for such a major

event), it would possibly cause thousands of deaths and destroy a large number of buildings, including public buildings useful for crisis management (hospitals, fire stations, schools, etc.). These dramatic consequences would be essentially caused by anarchic development of housings in dangerous areas and a global permissive attitude among local representatives (e.g. electoral considerations), regarding the application of appropriate anti-seismic design regulations (e.g. only 27% of housings are correctly designed in Guadeloupe).

However, recent earthquake crises (1999 in Martinique, 2004 in Guadeloupe) and local initiatives (e.g. training or regional "anti-seismic" building prime to encourage private owners to have their house built or controlled by specialists) have favoured a collective awareness increase. Up to these dates, there was a crucial lack of building specialists adequately trained to anti-seismic design rules, leading to design and execution mistakes. In addition, true preventive efforts have been made since 2000 in Martinique and 2006 in Guadeloupe, in order to reduce the human and technical vulnerability to seismic risks.

Another unforeseen positive consequence of the prime policy is that the Regional Council is considered as a good resource partner for medical workers, district associations, schools or any citizen willing to prepare to a catastrophic event or prevent it: it is their favourite canal for technical or legal information, etc.

At the national level, the 2004 crisis has led to the amplification of the institutional efforts regarding seismic risk prevention and mitigation strategies, resulting in the launching of the National Seismic Plan in 2005 (to end in 2010) by the French Ministry of Ecology. Within this framework, Guadeloupe has launched a large program to assess the physical vulnerability of schools since 2006. Some national emergency exercises (RICHTER National Exercise[2], 2008) have also been organized in some French departments (e.g. "RICHTER 13" in 2007, "RICHTER Antilles" in 2008, "RICHTER 65" in 2009).

The success of this plan in the French West Indies was not as expected for the first years, due to a number of local social factors which appear in the post-seismic surveys (e.g. see Cartier & Colbeau-Justin, 2007; de Vanssay, 2007). For instance, it appeared that initial institutional documents were too much focused on specific hazards (e.g. seismic site effects and liquefaction) at local scale (district, village, etc.), which was confusing and misinterpreted by the population (*scientific jargon*), whereas the anarchic housing development is a national scale issue. Moreover, the media or supports used to communicate on the subject were not adapted to the social context. Finally, people generally feel either worried or suspicious about the official information (social study after the 1999 Martinique earthquake: e.g. see Leone & Mavoungo, 2000). Thanks to the outcomes of post-seismic surveys, efforts have been made regarding information dissemination and awareness mechanisms, to fit the local social features and concerns (e.g. "Sismik"[3] and "Réplik" campaigns organized annually respectively in Guadeloupe and Martinique).

5.1.3 Vulnerability changes after the Friuli earthquakes of 1976

On May 6, 1976/on September 15, 1976

On the 6th of May 1976, a 4.5 magnitude earthquake, followed by a 6.4 one a minute later occurred in Friuli, Italy. The area was affected severely, 950 persons died and more than 2.500 were severely injured; 12000 houses were destroyed and 25000 were damaged. After four months, on September 15, during reconstruction works two strong shocks hit the area again. First one was at 5:15 a.m. with a magnitude of 6.0 on the Richter scale and the second one was at 11:23 a.m. with a magnitude 6.2 on the Richter scale. (Cattarinussi, 1981) Due to the shocks in September, the reconstructed areas after the first earthquake in

[2] http://www.planseisme.fr/spip.php?article9&var_mode=calcul#
[3] http://www.brgm.fr/AgendaNews/dcenewsFile?ID=764

May collapsed again. Having two devastating earthquakes with four months interval make the Friuli case suitable to study the effects of successive disasters on the community.

Pre-disaster phase

Friuli is located in the Northern Italy near to the borders of Austria and Slovenia. During 1960s and 1970s, its economy was dependant on agricultural productions. In this period, due to the limited non-agricultural production, people emigrated from the area. Owing to this situation the agrarian sector which was only 39.8% of the job sector in 1952 decreased to 7% in 1976. While the economy of villages depending on the agrarian sector was declining, there were also villages which have the secondary and tertiary sector productions as the attraction centers for both young people and economic investments (Barbina, 1979). Besides, emigration leads to increased levels of the physical, economic and demographic vulnerability, because of the unattended houses, low income, a limited network of firms, declined agricultural production and the high presence of elderly people with limited physical capability.

Post-disaster phase

Just after the disaster, military and firemen organizations responded to disaster in an effective way. Military intervention was very rapid, because the event area was very near to the border where an Italian Army was permanently located. In addition, foreign countries, especially Germany and Austria sent their relief organizations to supply the aid demand. (Cattarinussi, 1981) Surveys showed that there was a huge amount of community help as happens in many catastrophes. As Cattarinussi indicates, Fruili earthquake signified that some communities could be more efficient than other communities while responding to the same hazard. Although Yugoslavia is also affected from the same event, their community response was more organized, efficient and effective than in Italy. At this point, "Which conditions could lead this difference?" is an unanswered question that need to be asked.

The Friuli case has been the subject of research to understand the changes on human behaviour and reasons of conflict. Results showed that just after the disaster conflict was at its lowest level. Dynes and Quarantelli (1971) group the reasons behind the low conflict in the following five:

1. "A consensus on a hierarchy of values quickly emerges within the community.
2. Emergency period problems require immediate and obvious actions
3. Disasters produce an orientation to the present which minimizes previous memories of and future opportunities for conflict
4. Disasters reduce status differences
5. Disasters tend to strengthen community identity"

Cattarinussi (1981) also points out a low level of conflict owing to his interviews with children; and he continues by saying that: "a decrease of parochialism is also reported as is a rising sense of ethnic awareness". Furthermore, other contributions about this issue come from Wolfenstein (1957) and Taylor et al. (1970) in which they mentioned about a growth in internal solidarity that helps to increase cooperation and mutual help connected to the low level of conflict.

Reconstruction Phase

During the reconstruction period, when the regional administrative authority started to prepare the reconstruction plans, town planners contributed by making blueprints on areas away from the dangerous zones where to concentrate the population. Residents protested these projects through their town councils. Then, the parliamentary elections that occurred on 20th of June, 1976 had prevented the reconstruction plans owing to the politician's behaviour that is to evade from unpopular precautions; like providing barrack settlement zones. As a result of the public pressure, the right of plan making was given to each municipal administration. The Autonomous Region of Friuli steered the reconstruction and some prefabs were built on the Adriatic Coast. In addition to this new establishment, Friuli was also built according to "where it was, how it was". (Cattarenussi, 1981) "In the restoration phase people try to regain acceptable conditions of life and to re-establish the exercise of the essential functions of an organized life" (Barbina, 1976) In a very short time owing to the fast reconstruction most of the industry workers went back to factories and many people moved to their rebuilt houses.

Repetition of earthquake

On 15 September 1976 there were two strong shocks at 5:15 a.m. (6.0 Richter) and 11:23 a.m. (6.2 Richter). "Even though the quake is weaker than the first on May 6, the psychological effects on the people were much worse this time." (Geipel, 1981) The communities who were still suffering since four months were affected badly. Thousands of restorable buildings, to which people had already returned, collapsed. "Bad landslides and rockfalls blocking escape routes out of the mountains, the loss of saving what had already been invested in reconstruction; the dangers of the severe mountain winter in prospect, all overwhelmed the resistance capacity of a mountain population accustomed to privation." (Geipel, 1981) After this repeated shock "ordinary situation recalled". As many as 32.500 individuals left the area. While part of the population was evacuated, the reconstruction activities began again and were completed by spring 1977.

As Fritz said in 1961:

"The renovation of the actors within the system and the consequent total concentration of societal energy on the goals of survival and recovery usually result in the rapid reconstruction of the society and, beyond that, often produce a kind of "amplified rebound" effect, in which the society is carried beyond its pre-existing levels of integration, productivity and capacity for growth." (Fritz, 1963)

In terms of conflict, it can be said that it increased due to the two main reasons. Firstly, it is mostly about allocation of resources. In the emergency period freely given resources are distributing with a bureaucratic way in the restoration period and lead the conflict to increase. "Question of need, financial responsibility and intended utilization all became relevant." (Quarantelli & Dynes, 1976) Secondly, during the emergency period many organizations have emerged to deal with the disaster and allocation of resources. When the external aid has been cut out, resources have decreased in amount. This situation could have led to a conflict between newly established organizations and traditional ones to undertake the certain tasks about who is going to do which activities or who has the legitimate right to do. (Quarantelli & Dynes, 1976)

Conflicts could be both dysfunctional and functional depending on the type of the conflict which could be political or inter organizational. But no one could say that conflict has an absolute negative or positive affects to communities aftermath a disaster.

This multi-dimensional nature of conflict entails a set of questions:

Is there a connection between conflict and resilience? Having less conflict in the emergency period and having more conflict in the reconstruction period, could both lead to increase the resilience? Do we need conflict to improve the situation? Do we need a more passive and

hierarchical pattern in the emergency period to act more rapid? Having debates and conflicts in the reconstruction period make the things complicated or force the people to find good solutions?

What has changed in Friuli in terms of vulnerabilities?

To sum up, in the pre-disaster period the physical, economic and social vulnerability were high in Friuli due to the unattended houses, low income, a limited network of firms, declined agricultural production and the high presence of elderly people with limited physical capability. After the disaster many funds flew in the area from other nation, neighbors and emigrated people who are living other countries. Due to its location that is near to the other countries and big industrial cities the area attracted the industrial investments and led to have gradual improvement of the region. This new investments invite the youth back to their homeland. Gradually the economic and social vulnerabilities of the area have decreased. As for the physical vulnerability, the construction occurred both in the historical centre and new development areas. The central area was become less vulnerable due to the renovation and reconstruction processes. However, the changing housing pattern did not fit the society's need and affect them negatively.

The second earthquake in September had an immense effect on all the vulnerabilities. As for social vulnerability, people become more apathic. They lost their willing and attention. Many left the region, disoriented and alienated. These conditions increased both physical and economical vulnerabilities. However, this situation had recovered by the time with the help of the reconstruction processes and industrial improvements.

5.1.4 Evolution of institutional vulnerability to earthquakes: Legal framework changes after earthquake events in Turkey

Despite there had been several devastating earthquakes on the Anatolian Plate in the history, earthquake mitigation efforts were set not earlier than 1940s, neither during the Ottoman Empire nor the first years of the foundation of the Turkish Republic. The only tangible regulation during the Ottoman Empire to reduce the probable losses of future earthquakes was after the devastating earthquake of 1509 that Sultan Beyazit II prohibited development on the filled land and encouraged new buildings to be constructed in wooden structure rather than masonry (Genc and Mazak, 2000).

In 1939, the most deadly earthquake in Turkish Seismic History occurred in Erzincan (Turkey) where 32.962 people died and 116.720 buildings totally collapsed. Immediately after the earthquake, the law number 3773 on "Assistance for earthquake victims at Erzincan" was issued. This law was the first legal frame concerning disasters directly. Between 1942-1944, other four devastating earthquakes occurred on the Anatolian Plate which urged the emergence of new regulations. In 1944, the Law 4623 was issued concerning prevention and reconstruction measures before and after earthquakes. Following this law, in 1945, the first earthquake hazard map for Turkey was prepared by the Ministry of Public Works and Settlement with collaboration of academia.

After 1950s, rapid urbanization was fed by mass immigration flows from the rural parts through the big cities of Turkey. Current plans and development pattern of the time fallen behind this course. The same period was fruitful in setting regulation to reduce losses by earthquakes and other hazards. However, amnesty laws, issuing mostly before election periods, for legalization and rehabilitation of illegal housing development let the attempts insufficient to reduce earthquake risks.

a. Contemporary Legal system in Turkey for disaster management

Disaster mitigation planning policies are classified into two focuses, pre-disaster and post disaster activities. The focus of Turkish legal system has changed from post disaster to pre-disaster activities after the earthquake in 1999 in Kocaeli. The focus of pre-disaster activities is on reducing the possible risk before the event occurs. On the contrary, post disaster approach pays attention on the activities after event occurs. The main reason behind this choice is that vulnerability is an invisible issue and one may not be sure whether a disaster will happen or not. In Turkey, before the Kocaeli event, focus on post disaster activities gives a role to the state as the main compensator of earthquake losses based on the disaster law (Taylan, 2005).

To clarify profoundly the legal system of Turkey, firstly there is a need to look at the 1982 constitution. "The Emergency State" term and its regulations, rules, role of the authorities are elucidated. It can be claimed that in the 1982 law the attention is on the post disaster activities. Furthermore, the role and the place of the local and central authority are stated clearly in these activities. Secondly, there is a disaster law directly related to disaster (Law no: 7269). It focuses on the emergency preparation plans during and after a disaster, and also, the regulations of the aid organizations. This law is issued by Ministry of Public Works and Settlement and this administrative unit issues also the "building codes and structure law". However, there cannot be mentioned about an interaction between these two laws, which is necessary during the implementation. Thirdly, in Turkey State Planning Organization has responsibility to prepare the national development laws and 8th national development law is also related with the disaster mitigation strategies. Finally the compulsory earthquake insurance is analyzed. 8th national development law and compulsory earthquake insurance reveal the effects of Kocaeli earthquake on the legal system and they are the clues of changing point of view from post-disaster to pre-disaster activities.

b. The 1982 Constitution

Initially, in the 1982 Constitution of Turkey, the conditions of "The State of Emergency" have been explained in the articles 15, 119 and 121. These articles are not directly related with the disaster management however they describe the rights, rules and administrative procedure during an emergency period. Article 15 is more general than other and declares the fundamental rights and freedoms in "The state of Emergency", article 119 is about disaster declaration and finally article 121 lists the rules of "The State of Emergency". During the state of emergency, the Council of Ministers meeting under the chairmanship of the President of the Republic may issue decrees having the force of law on matters necessitated by the state of emergency. These decrees shall be published in the Official Newspaper, and shall be submitted to the Turkish Grand National Assembly on the same day for approval; the time limit and procedure for their approval by the assembly shall be indicated in the Rules of Procedure.

c. The Disaster Law (Law no: 7269)

The disaster law issued in 1959 and revised in 1968, is the primary law to cope with disasters. It is directly related with the disasters and aims at providing public intervention capacity and improving the efficiency of relief operations after disasters. According to this law, during a disaster the provincial and district governor have the powers to control public, private, and even military resources to manage response activities. Each ministry, provinces should have its own emergency preparedness plan. Before the event occurred, they should know what they would do during a disaster. Every year from the national budget a fund was allocated for recovery expenses. The disaster law also states regulations concerning

emergency aid organizations, general public affected by disasters, disaster affecting individuals, buildings, leftover buildings and lands after a disaster, expenditures, and funds and for structures to rebuild in disaster zones.

d. National development law

National development laws are issued by the "State Planning Organization" every five year. Nowadays, the "9th National Development Plan" is in validity that is for between 2007 and 2013. However, unlike the "8th National Development Plan", in this plan there is any mention to natural disasters, on the contrary, it is mostly about economic resilience. In the former one in the section seven "Natural Disasters" and chapter nine "Enhancement Efficiency in Public Services" are focused on the disaster issue. The reason behind this focus is that the 8th national plan submitted right after the Kocaeli earthquake and was valid between 2001 and 2007.

As a detailed critique for the "8th National Development Plan", the objectives and principles are mainly about setting up and creating integration between the social, legal, institutional and technical structure to reduce the damage of a disaster. The plan also mentioned the importance of educating people in a continuous and systematic way to achieve the perception of natural phenomenon as common natural events. Besides, plan supports to have earthquake engineering postgraduate programs in qualified universities. The plan is not focus only after the disaster process it also claims that a small part of resources should be used before the disaster to reduce the damage. Furthermore, firstly in the high risk zones than in the parts of the city building stock should be examined and strengthened against earthquake.

In this development, law stresses also on the agreement that should be existed between legal, institutional and technical patterns of a National Extraordinary Situation Plan. According to the 8th National Development Law, the system is following rules of this plan should succeed in decreasing economic, social and physiological harms due to disasters and at the same time cover rapid, efficient and complete rescue operation before, during and after a disaster occurred.

e. Compulsory Earthquake Insurance (Decree no 587)

Issued by the Undersecretaries of the Treasury, this directive regulates the manner in which insured parties shall make claims for losses against the Natural Disasters Insurance Council (DASK is the Turkish abbreviation). The amount payable by DASK essentially covers the minimum amount required for a modest new accommodation. Homeowners can, of course, purchase additional voluntary insurance if their property is worth more. TCIP coverage is for property only and does not extend to contents or life. The payments of TCIP will be proportional to actual losses. TCIP is a policy that specifically covers the earthquake peril. Secondary effects of the earthquake are also covered.

According to the "Compulsory Earthquake Insurance", all existing and future privately owned properties are required to contribute to the Turkish Catastrophe insurance Pool (TCIP). Non-engineered rural housing, state buildings and fully commercial buildings are excluded. The intention of this decree is to create a fund contributed to by homeowners' annual payments for use in disasters so that no one will be left homeless, with a nominal sum, currently capped at US$28,000, being disbursed immediately to homeowners who are left homeless.

f. Evaluation of Legal System in Turkey for disaster management

To sum up with the assessments of the legal system, it can be said that laws are far from being related with complementary disaster management plans, however projects filled up this hole.

Laws are partially integrated with each other. In addition to this, their importance has been realized after the Kocaeli Earthquake and issued with the effects of that. Due to this, they are mostly related with earthquake. Firstly, 7269 disaster law is mostly focused on the situation after the disaster happened. By giving attention to the emergency activities and the responsibilities of the emergency aid organizations, it is totally a disaster law that stresses on the post disaster activities and aiming to decrease the chaos after a catastrophe happened. It is very clear that the emergency needs of a landslide, flood or an earthquake and also their effects, the dimension of the effects are totally unlike. However, in this law there is no classification of diverse types of the disasters and different needs according to risk type. Finally for this law it can be said that for the period after a disaster occurred to carry out the situation fully responsibilities given to the local authority. When disaster happened, firstly local authority can reach the area and understand the situation before others. However, in addition to giving the responsibilities to them there should be dictated also some obligations regarding organization, training and enforcements. This is also due to the giving the importance after the disaster period. Because of this, the organization of teams their education and enforcements of the operations are not taken care of. This is like putting into the deep water the local governments and hopes to achieve to swim without giving any instruction just watching to them and praying.

While 8th national development law and compulsory earthquake insurance have focusing on the pre-disaster activities by using risk mitigation and preparedness tools, on the contrary, disaster law stresses on the emergency activities for post-disaster period. The settings and objectives of 8th national development law clearly state the importance of pre-disaster activities. It gives importance to make people aware about the present danger. Compulsory earthquake insurance also gives importance to create an insurance pool before a disaster to decrease the burden on government's shoulders.

Referring the legal framework in Turkey and best practices in mitigation projects on Istanbul, some important remarks reveal to better understand the hidden facets of vulnerability and clues to achieve resilience at every level of communities:

- Vulnerability is a continuous process, a snow ball which may expand through different levels during the time span.
- Vulnerability is mostly fed by upper level of decision making and diffuses through lower layers e.i. individuals, single buildings.
- Precautions taken and/or regulations issued to mitigate risks should be evaluated equivalent legal aspects concerning conflicts to reduce negative impacts of natural hazards.
- Post-disaster focused communities are used to cope with the devastating consequences of natural hazards, however, reconstruction process is barely not concentrated on resilience at physical, social and economic environment which may lead further disasters in future (bouncing and getting the initial position).
- Stressing on pre-disaster activities requires extensive measures taken at every level of society which may encourage increasing awareness and shift in behaviour.

5.2 The impact of successive disaster cycles on territorial and eco-human systems' vulnerability – Determinant factors

5.2.1 Forest fires in the Mediterranean Region

a. Ecological vulnerability to forest fires in the Mediterranean

The importance of the Mediterranean forest ecosystem is well expressed by its biodiversity richness. It's mosaic of forest types hosts approximately 25,000 vascular plant species that are important not only because they represent 10% of the world's flowering plants, but also because more than half of these species (an estimated 13,000) are found nowhere else in the world (WWF, 2004). On the other hand, the vulnerability of Mediterranean forest ecosystems is also known to be high. Although the dominant pine and oak species are fire-adapted species – this is, they depend in part on fire to regenerate – the frequency and severity of the fires regimes in the Mediterranean is one of the leading causes of forest degradation (EEA, 2007). Since 1960, the burnt area in Europe has quadrupled, and forests are not able to regenerate at this rate of fire return (WWF, 2004).

Fires in Mediterranean ecosystems have a complex effect on geomorphologic processes and vegetation regeneration due to the complexity of landscape structures as well as differential responses of such systems to various types of fire regimes. In spite of the considerable efforts invested in fire research, the ability to predict the impact of fires on the landscape is still limited (De Luis et al., 2004).

Forest fire represents a major agent promoting changes at the landscape level and increasing land degradation risk. The ecological vulnerability to fire can therefore be defined as the susceptibility of the ecosystem to be changed as a consequence of fire. Environmental features, as well as vegetation structure and composition in combination with fire frequency are key factors to estimate that vulnerability. The impact of successive fire disturbances for the ecosystem can broadly be broadly grouped into two time scales. A short-term perspective that focus mainly on soil degradation risk and consequent impact, and a medium-term perspective that focuses on changes in plant composition and structure.

b. Vegetation changes after successive fire events

Changes in the structure of vegetation recurrent from post-fire vegetation recovery are an obvious consequence of the impact of successive fires in a landscape.

Post-fire vegetation regeneration has been extensively studied throughout the world. In the Mediterranean region, the post-fire recovery process of the burned ecosystems has been clearly identified through many studies, and the adaptation mechanisms have been well established (Trabaud, 1994 and Tsitsoni, 1997).

The recovery process depends, among other processes, on how long the time interval between fires is and the type of ecosystem, for example, in the case of Pinus halepensis forests, it is estimated that full recovery requires more than 30 years (Arianoutsou and Ne'eman, 2000).

On the Mediterranean coast of Spain, forest fire frequency has significantly increased over the last decades (Pausas, 2004). As a consequence, shrub vegetation communities dominated by obligate hard-seeder species have become widespread. In eastern Spain, the most common shrubland community is dominated by Fabaceae species (mainly Mediterranean gorse; *U. parviflorus*) while Cistaceae and Lamiaceae species (mainly *C. albidus* and *R. officinalis*) are present as subdominant shrubs.

A case study (De Luís et al, 2006) conducted in the region of Sierra de Onil, Spain, demonstrate that for a fire recurrence period of 12 years the vegetation regeneration after

fire does not display the normal auto-successional pattern and produces a change in dominance species, from Fabaceae (mainly *U. parviflorus*) to Cistaceae (mainly *C. albidus*) species. Given that fire frequency, intensity or severity is partially controlled by the composition and structure of the plant community (De Luis et al., 2004), population changes can have implications for conservation, since they affect the hydrological, ecological and economic role of woodland areas in western Mediterranean ecosystems.

A different study now conducted in the area of Penteli, central Greece (Goudelis et al., 2007) estimated the differences in soil and vegetation composition, density and growth between *P. halepensis* dominated communities that were burnt once (1998) and communities that were burnt twice in a short time interval (between 1995 and 1998).

Figure 19 displays the temporal evolution on stem density (in number of stem per square meter) in areas that were subject to one fire event (b1) and areas that were subject to two fire events (b2). It can be observed that the general evolution in time of stem density is quite similar; the main difference lays mainly on the magnitude of the values. Areas that were burned once present a step increase on stem density up to the 10th month of the study and a decline after. Areas that were burned twice also present and increase on stem density up to the 10th month; nevertheless, the values lag always behind of the values obtained in areas that were burned only one time for the entire time frame of the study.

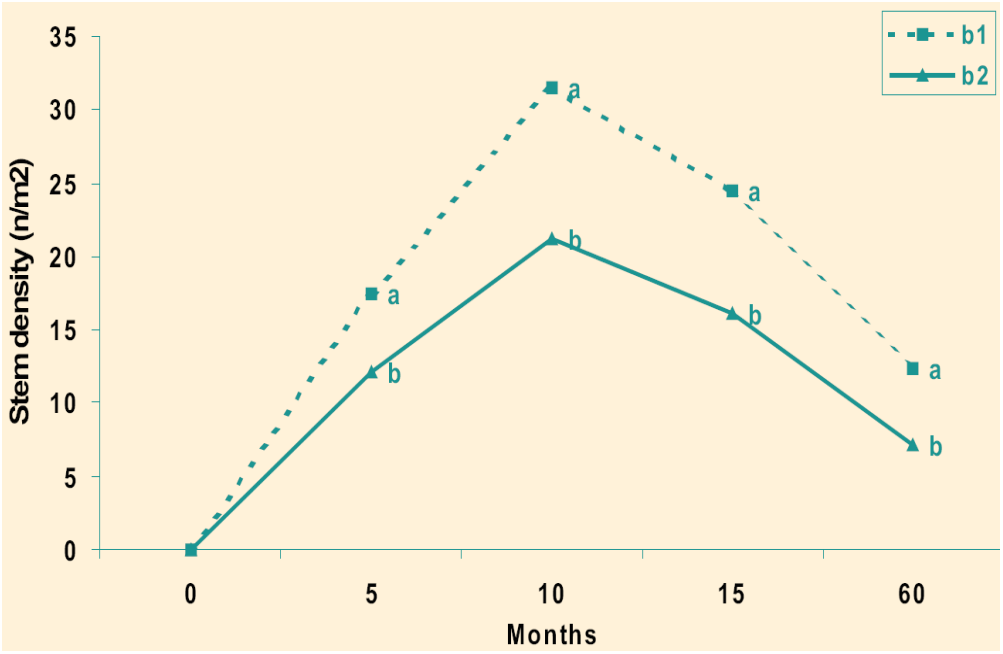


Figure 19: Post-fire vegetation density change in 5 years after the fire in areas burned one (b1) and burned twice (b2)

Changes in species composition were also noted, in fact, it's valuable to point that the vegetation density was further reduced during the next years mainly due to competition between the individuals. Table 12 show the results obtained on the species composition for areas that burned once and two times. Although resprouter species were more abundant in twice-burnt areas and the opposite was found for seeder species. No statistically significant differences were observed in the relative abundances of regenerative groups (Goudelis et al., 2007) meaning that this particular recurrence interval of fires is still in the range of resilience presented by the ecosystem.

Table 12: Values of the same species for the same parameter in areas burned once (B1) and (B2)

Species	B_1 areas		B_2 areas	
	Density (stems/m²)	Mean height (cm)	Density (stems/m²)	Mean height (cm)
Resprouters	**10,40a**		**5,40b**	
Quercus coccifera	6,65a	47,43ns	3,56b	52,74ns
Pistacia lentiscus	0,00	0,00	1,04*	65,77*
Phillyrea latifolia	0,16*	181,25a	0,07*	25,83b
Arbutus unedo	0,20ns	31,67a	0,21ns	110,71b
Nerium oleander	0,00	0,00	0,16*	136,14*
Erica arborea	1,50*	28,80*	0,06*	47,50*
Cotinus coggygria	1,45*	39,17*	0,00	0,00
Dittrichia viscose	0,00	0,00	0,18*	59,92*
Pistacia terebinthus	0,16ns	146,50a	0,12ns	51,75b
Olea europaea	0,28*	107,14*	0,00	0,00
Seeders	**1,96ns**		**1,77ns**	
Pinus halepensis	0,33ns	71,38ns	0,38ns	73,64ns
Cistus monspeliensis	1,10ns	38,02ns	1,39ns	42,81ns
Cistus creticus	0,25*	34,60*	0,00	0,00
Phlomis fruticosa	0,28*	112,00*	0,00	0,00
Total	**12,36a**		**7,17b**	

Based on the findings of the study, it was suggested that the repetition of wildfire in a short time affected negatively the ecosystem, and this could add to the risk of area degradation (Goudelis et al. 2007).

In addition, the implications of successive fire disturbances on forest ecosystems were found in other Mediterranean like fire regimes. For example, evidences form post-fire recovery rates after successive fire events in Mt. Carmel, Israel, for the period 1995 – 2002. The findings reveal that repeated fires and slope conditions further reduced recovery rates. Relative burnt/un-burnt ratio indicates that the lowest values were obtained at the three times burnt in the south facing slopes. Also, in the north facing slopes the ratio decreased with the increased number of fires, but to a lesser extent - 0.77 following a single fire and 0.61 following three events (Wittenberg et al, 2007).

c. Resilience

As with any disturbance, fire rarely erases all components of the original plant community. Rather, fire leaves traces or features of the original vegetation in form of biological legacies.

Results (Viedma et al 1997) have indicated that the pre-fire state of the disturbed vegetation and their natural history and penology are key factors in the recovery process after fire. The first one showed a close relation with the potential recovery capability according to the ecological theories of fire succession and the second ones play an important role in the speed with which some areas reach their maximum value in their biomass growing process. Snags, buried seeds, buds, and surviving organisms constitute examples of biological legacies after fire. These biological legacies are important not only for wildlife habitat, nutrient dynamics, and ecosystem function but also have an influence on the post-fire plant community composition and structure (Viedma et al 1997).

Ortiz (2008) argues that seed banking species and resprouting species dominated, showing the influence that the previous plant community had on the vegetation after disturbances (Ortiz, 2008). Twenty years after high severity fire, snags were still part of the structure of unmanaged sites. Snags contributed to the heterogeneity of the vertical structure of unmanaged sites and their presence in post-fire settings can influence some important site

characteristics such as soil moisture and evaporation. Due to the persistence of their seed, most of the resprouting species present quick rates of recovery in (Wittenberg et al, 2007).

With the use of multi-temporal Landsat images of the area of Ayora, Valencia (Eastern Spain), between the years 1984 and 1999, the post-fire regeneration of vegetation was analysed using the Normalized Difference Vegetation Index (NDVI) in areas subjected to different fire recurrences (Malak et al. 2006).

Results suggested that for the first 7 years after a single fire, NDVI depends mainly on the time since fire (post-fire regeneration), whereas environmental parameters (precipitation and bedrock type) are of little relevance. After this period, precipitation begins to have a direct influence on the NDVI. In patches burned twice, with fire intervals of 8 and 9 years, NDVI is also controlled by the time since fire. Furthermore, NDVI recovery is faster after the first fire than after the second fire, suggesting that fire recurrence has a negative impact on the resilience of these communities. Bedrock type did not show any effect on NDVI after fire (Malak et al. 2006).

Changes in ecosystem functions following disturbances are challenged to understand the factors that affect the resilience of community structures and ecosystem functions. Moretti (2006) assessed rresilience by analyzing arthropod species composition, abundance and diversity in plots where the elapsed time after single or repeated fires varied. Data from burned plots was compared with data from plots that had not burned within the last 30 years and defined high resilience as the rapid recovery towards the non-fire species composition (Moretti et al. 2006).

All functional groups pooled were more resilient to single fires than to repeated events, recovering 6–14 years after a single fire, but only 17–24 years after the last of several fires. Flying predators and herbivores arthropods were the most resilient groups. Pollinators and epigaeic predators showed intermediate resilience, while decomposers and wood-eating arthropods clearly displayed the lowest resilience to fire. Their species composition 17 – 24 years post burn still differed markedly from that of the unburned control plots. Depending on the fire history of a forest, it was found significant changes in the dominance hierarchy among invertebrate species (Moretti et al. 2006).

The results indicate that Mediterranean systems are quite resilient, showing quick response, at least in terms of return to previous states of soil erosion rates and vegetation cover not only in a response to disturbance caused by a single fire effect, but also to repetitive fire incidents (Wittenberg et al, 2007).

At medium-term, the ecological vulnerability was determined by the capacity of the community to return after fire to the pre-fire conditions without significant changes in composition and structure (resilience). This capacity was associated with the presence/dominance of species with different reproductive strategies, structure of the community and fire frequency.

Results (Torres 2006) conducted in a mediterranean shrubland-open context pointed that the vegetation community in the first post-fire year was spatially structured with a positive spatial cross-correlation between plant cover and species richness, indicative of areas with high plant cover and species richness and vice versa. The second year after fire, patterns became less evident and no clear spatial cross-correlations was detected at any scale. These results suggest that after a fire the community is structured as a result of the ecological memory of the system, which is not overridden by fire. In subsequent years the patterns are modified by the dynamics of the flora, particularly the annuals, producing lack of patterning.

d. Soil degradation/erosion

Forest fires lead to soil deterioration, causing large soil losses during rainfall and deterioration of downstream water quality. It is expected that, if current frequencies of

wildfires persist or increase, there will be some major consequences for soils and for run-off. Physical and chemical soil erosion increases with decreasing soil thickness, leading to decreased soil fertility and carbon sequestration capacity. Surface run-off can also increase the likelihood of floods (Pereira et al, 2004).

The coupled effect of vegetation destruction from a forest fire and changes in soil properties (Cerda and Doerr, 2005) inevitably leads to a rapid increase in soil loss and runoff processes.

Increased erosion after wildfire derives primarily from the destruction of vegetation and changes in the soil physical and hydrologic properties that reduce infiltration rates and increase availability of loose sediment (Ferreira et al., 2005). The loss of vegetation and other ground cover due to wildfire reduces rainfall interception and attenuation, rainfall storage and flow resistance (Martin and Moody, 2001).

Rainfall-generated runoff therefore accelerates quickly and less is retained as pounded water, resulting in reduced residence times and reduced total infiltration. Runoff peaks sooner and at higher magnitudes than on vegetated slopes, resulting in greater shear stresses acting at the soil surface to detach and transport sediment. Fire also consumes the shallow roots that contribute to soil strength (Hyde et al., 2007).

The increasing frequency of fires and their repeated incidence in previously affected zones accelerate soil degradation processes by enhancing the effect of water erosion.

The importance of the fire regime characteristics, both intensity and frequency, are crucial on determining the magnitude of soil erosion events following a severe fire disturbance. With much of the sediment loss occurring during the first year following the fire occurrence (Cerda and Doerr, 2005), it is evident that rapid regeneration of vegetation cover becomes key factor in the rehabilitation of the landscape and an indicator for the resilience of the eco-geomorphic system. In addition, risks of post-fire soil erosion are higher when the time required for the vegetation to reach this minimal vegetation threshold cover is longer. This has been widely demonstrated at various spatial scales and under different ecological conditions (Inbar et al., 1998 and Cerda 1998). If the recurrence time of a fire exceeds the threshold of minimum vegetation recovery post fire erosion processes are considerably enhanced leading to a higher risk of soil degradation.

Rainfall characteristics and the time between fire and the first intense rain are key factors influencing runoff and sediment yields on burned slopes. Another factor that also could play an important role in the hydrological soil response is the ash layer that covers the soil surface after fires. It can contribute to increase runoff and sediment transport by surface sealing and can also act as a protective layer reducing the impact of rain drops and soil detachment (Campos et al., 2006).

5.2.2 A series of Natech events after the Katrina flood and oil contamination events of 2005 in St Bernard Parish on repercussions' vulnerability

For a general description of the flood and chemical spillage in St. Bernard Parish after Hurricane Katrina (2205) see section 6.1.2 and Del. 2.1. Here, the focus is upon vulnerability evolution through successive disaster cycles.

During the 4-5 year period of the case study (i.e. August 2005 to January 2010) and since Hurricane Katrina, New Orleans and St Bernard parish have experienced a series of hurricane emergencies, with at least one leading to flooding close to St Bernard parish. St Bernard parish remains highly exposed and vulnerable to further tidal surge flooding. These emergency events include:

- November 2005, Hurricane Rita;
- August 2008, Hurricane Gustav;
- September 2008, Hurricane Ike; and
- November 2009, Hurricane Ida.

None of the subsequent hurricanes proved to be as extreme as Katrina in terms of flooding. However, hurricane Rita struck St Bernard parish soon after the Katrina flood, and floodwaters once again poured into the parish through the levees breached in August 2005. There had not been time to repair the breaches. Hurricane Gustav led to a mandatory evacuation of St Bernard parish and damaging flooding was only very narrowly averted as breach repairs had by then been made. In this event a levee close to St Bernard was overtopped but engineers managed to divert floodwaters along a river diversion channel. Hurricane Ike led to a voluntary evacuation of St Bernard parish (http://www.nola.com/hurricane/index.ssf/2008/09/parts_of_st_bernard_under_volu.html) but no significant flooding, and hurricane Ida led to another emergency in which sandbags were issued to property owners but no significant flooding occurred.

Given the continued susceptibility to flood loss in the post-Katrina disaster period, the effect on the evolution of vulnerability needs to be taken into account by extending the single disaster event cycle analysis performed in Section 4.1.2. (i.e. Figure 7, Table I in Appendix) to take into account a following disaster. In this case study a following emergency is substituted for a following disaster in order to model the effect on vulnerability of one event followed by another (although in reality St Bernard parish has experienced a sequence of following emergencies as explained above).

The analysis is performed using the DRV scale in Table I Appendix, and an example of the results is summarised in Figure 20 below. A similar summary analysis may be displayed for each of the four facets of vulnerability. With such an exceptional, devastating flood, coupled with the oil contamination, affecting a relatively disadvantaged community and a slow recovery it is not surprising that vulnerability levels are very high. The analysis reveals that, with one exception, vulnerability increases to extreme levels (DRV7) in the emergency relief period (which in this case is the 18 month period following the initial disaster), whereas, with one exception, in the single (isolated) disaster analysis in Figure 7 vulnerability either remains the same or decreases in this period. This is because the levees which were breached in the Katrina event remain unrepaired for a period of time during which the next hurricane emergency and flooding occurs. At this stage those who had returned to the community faced a capacity to recover from vulnerability and a renewed susceptibility to loss (mainly of their own lives). In most cases (see Figure 20) vulnerability remained higher (compared with the single isolated event) during the recovery and reconstruction period unless evacuees had resettled elsewhere, had not yet returned or were oil company employees. The analysis can be taken further to model the possible vulnerability impact of a future improvement to the flood protection standard afforded by the levees (Figure 21). Vulnerability to future emergencies and disasters would then decline further than in the final (DRV) column in Figure 20.

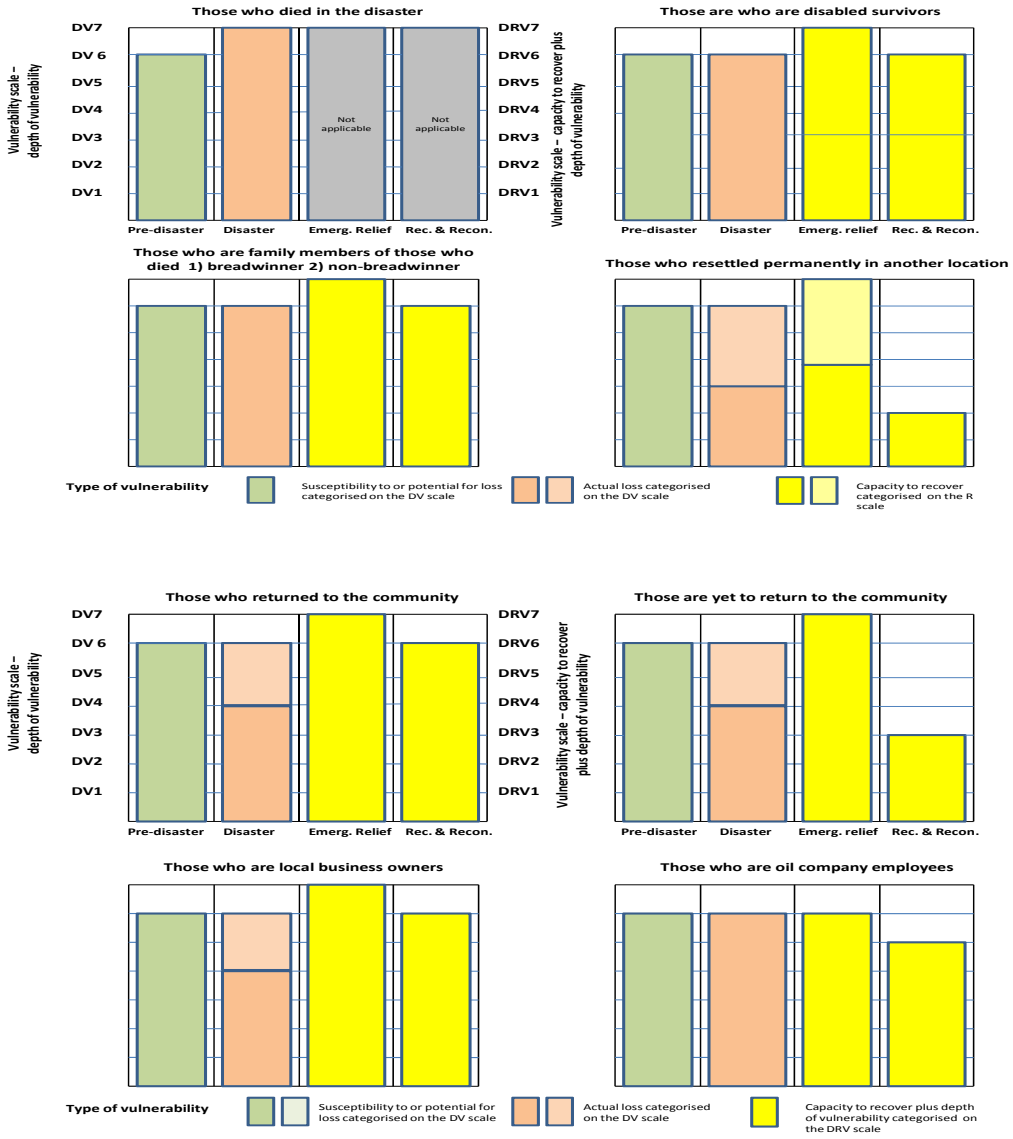


Figure 20: A vulnerability landscape for economic vulnerability for different segments of population of St Bernard parish for successive flood surge disasters/emergencies

Figure 21 postulates four different general vulnerability curves over time, drawing on the analysis above. In these curves all facets and all population segments are lumped together: hence the term 'general vulnerability curves'. Each curve would actually start at the same point on the vulnerability axis but have been separated here to aid visual interpretation. The recovery and reconstruction phase is thought of in two ways a) as a phase in which there is no improvement in the standard of flood protection (i.e. levees are restored but not heightened) and b) an improvement in the standard of protection eventually takes place. The red curve shows how vulnerability might be expected to increase and decrease when a single isolated disaster cycle is considered and the possibility of improving flood protection does not arise. The blue curve factors in the additional vulnerability (i.e. susceptibility to loss) that must be added to the incapacity to recover type of vulnerability in the emergency relief phase, and so vulnerability is heightened through this phase until recovery capacity improves forcing the curve downwards. The black and green curves also factor in the start of a second disaster cycle, with the green curve only modelling an improvement in the standard of flood protection in the second phase of recovery and reconstruction.

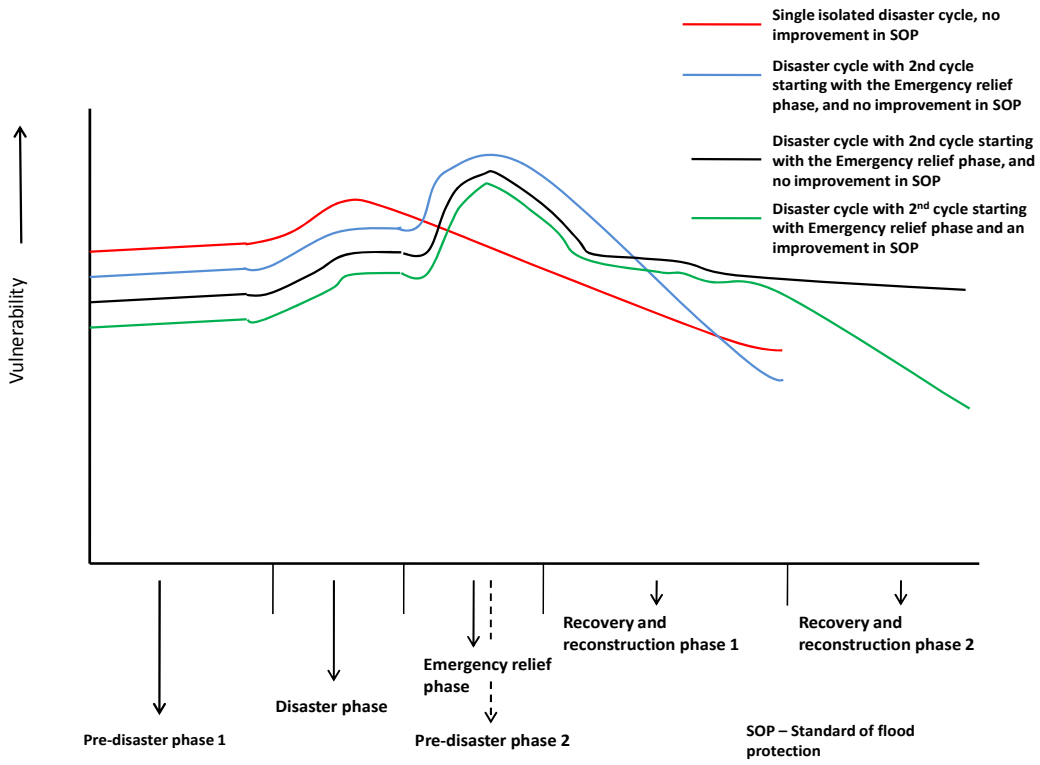


Figure 21 Postulated general vulnerability curves for single and multi-disaster cycle situations

6. Vulnerability actors steering vulnerability changes along the successive stages of a single and/or successive disaster cycles

This chapter includes two sub-chapters; Sub- chapter 6.1 deals with the micro and macro-scale single social economic and institutional actors regulating own and others' vulnerability using the examples the Achellos River Diversion and the flooding and chemical spillage in St Bernard Parish while Sub- chapter 6.2 deals with the predominant 'Vulnerability Actors' of territorial and eco-human systems managing territorial and ecosystems vulnerability using the examples of Leros; Northern Negev; and Abruzzo earthquake

6.1 Micro and macro-scale single social, economic and institutional actors regulating own and others' vulnerability – Critical forms of capital

6.1.1 Acheloos River Diversion as a Response to the Agricultural Drought of Thessaly, Greece: The Multi- level Actors involved

a. Introduction

This case study concerns the project of the diversion of Acheloos river in Greece, which flows in a north – south direction from the northern mountains of the Pindus range to the Ionian Sea, to the plains of Thessaly, in particular into Pineios river, for irrigation and other

purposes. This complex and very expensive project and the controversy surrounding it has occupied the centre of public attention in Greece for several decades and has caused bitter disputes between proponents and opponents and between the communities involved, i.e. the department of Aetoloakarnania, where most of the Acheloos river basin is located and the region of Thessaly, of which the farmers expect substantial benefits from the diversion.

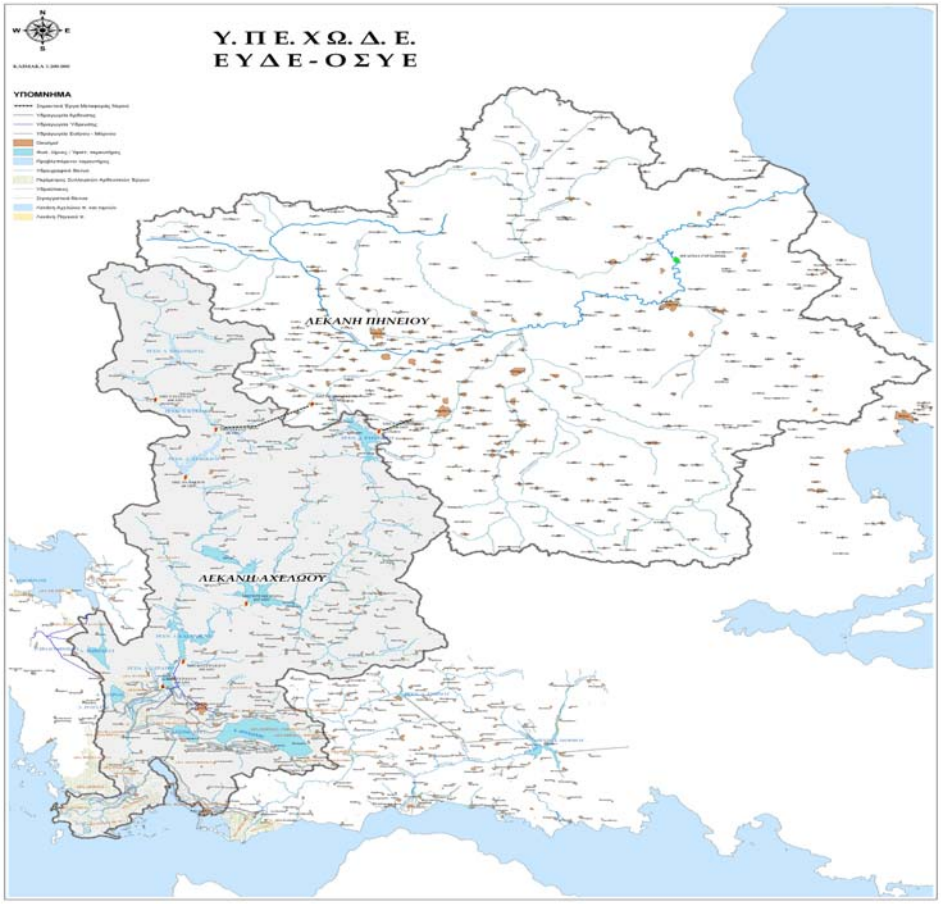


Figure 22 Map of the project area: The Acheloos river basin in grey and the Pineios river basin in white (Source: Ministry for the Environment, Energy and Climate Change)

The idea for a diversion was first floated in the 1920s and the first serious studies were commissioned in the late 1960s, but the first time the central government committed itself to realize the project was in 1983.[4] However, the dream of plentiful water supply from Acheloos was already well established among the farming community of Thessaly long before that date. Since then an extraordinary number of studies, reports and environmental assessments were produced, extremely costly construction has taken place, loud protests were voiced, environmental and activist organizations intervened and lodged appeals to the courts, and a series of resolutions of the Council of State, i.e. of the supreme administrative court, annulled governmental decrees and ministerial decisions concerning the implementation of

[4] For a review of the history of the project see Technical Chamber of Greece, 2005 and 1993a-b, ENVIPLAN, 2004, Leontaritis, 1999, and National Technical University Athens, 1995. For the compilation of this case study we reviewed reports and articles published in the daily press, especially in the daily *Kathimerini*, over a number of years.

the project and its individual components.[5] The project included the construction of large dams, water reservoirs, water deviation tunnels, hydroelectric power stations and an extensive irrigation and drainage system. Although the initial ambitions, as measured by the total flow volume to be diverted, were later somewhat lowered and adapted to a more modest scenario, which was described as a "partial diversion", the project remained huge by the standards of public works in Greece, labelled by its critics as one of pharaonic proportions or of soviet mentality.[6]

Although large parts of the project, e.g. the two largest dams and the main water flow tunnel, have been constructed and the cost already incurred by the Greek state (the European Union refused to co-finance it) is enormous, its ultimate fate, particularly as an irrigation project, is still in doubt, because of fierce opposition and court entanglements regarding its constitutionality and legality, as its execution may contravene both national and European Union legislation. As expected, opposition originates mainly in Aetoloakarnania, represented by local government and local citizen movements, and focuses mostly on environmental issues and the degradation of valuable ecological resources, which also impacts on the local economy and the prospects of development, primarily of tourism. Practically all the large environmental NGOs of the country have lent their support to protesters and were among the first to challenge government decisions in the courts. On the other hand, support for the project came from administrative authorities, farming cooperatives and other organizations of Thessaly, but above all from two extremely powerful actors, the central government (especially YPECHODE, the Ministry for the Environment, Spatial Planning and Public Works) and the Greek Public Power Corporation. It should be noted that some of the project components (dams, reservoirs and power stations) can become operational solely for electric energy production, a possibility which could justify their existence even if the project's irrigation role is terminated. Attitudes on the side of central government seem to be changing after the October 2009 national elections and the formation of a new ministry (YPEKA or Ministry for the Environment, Energy and Climate Change), although the future is still unclear.

b. Geography

The Pindos mountain range extends from north to south and divides mainland Greece into western and eastern Greece, with Epirus and Aetoloakarnania on its western side and Macedonia and Thessaly on the eastern side. The river Acheloos originates at an altitude of about 2,000 metres in Lakmos mountain of the Pindus range, in the administrative prefecture of Trikala (region of Thessaly). It flows in a southward direction on the boundary separating the regions of Epirus and Thessaly (prefectures of Trikala and Karditsa). Further downstream, it follows the boundary between the prefectures of Aetoloakarnania and Eurytania and flows into the Kremasta reservoir. From there onwards it flows on the soil of Aetoloakarnania, into the Kastraki and Stratos reservoirs, then across the Panaitolikon range, forests and swamplands. It empties into the Ionian Sea, west of the town of Messolongi.[7] Pineios river originates in the Pindus range, runs in an eastward direction across the plain of Thessaly and empties into the Aegean Sea, northeast of Tempe, where it creates a large delta.[8]

[5] Between 1994 and 2009 the Council of State issued 7 resolutions upholding appeals against government decision (CoS, 1994 – 2009). A further resolution was issued in February 2010, freezing all further construction (*Kathimerini*, 11.2.2010).
[6] *OIKO of Kathimerini*, 12.12.2009.
[7] See Joint Research Centre, n.d., *Acheloos River Basin – Greece*.
[8] http://en.wikipedia.org. See also Joint Research Centre, n.d., *Pinios Pilot River Basin – Greece.*

The geographical department (*nomós*) of Aetoloakarnania (often mentioned on maps as Aetolia and Akarnania) is part of the administrative region of Western Greece and falls under the jurisdiction of the prefecture (2nd tier local government) of the same name. The administrative region of Thessaly comprises four prefectures (Trikala, Karditsa, Larisa, of which the capital cities bear the same name, and Magnisia, of which the capital is Volos). Although Thessaly's western section is mountainous, its largest part forms a fertile plain, considered as one of the most important agricultural areas of the country.

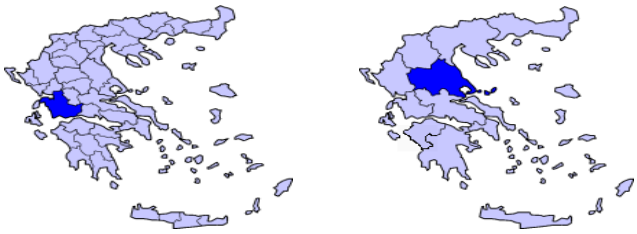


Figure 23: Location of Aetoloakarnania on the left, shown on a map of prefectures (NUTS level 3), and of Thessaly on the right, shown on a map of regions (NUTS level 2)

c. Outline and context of main events

The original idea for a project of such proportions is typical on one hand of a period of blind confidence to engineering possibilities and, on the other, when embraced by the socialist government of the early 1980s, of the populist ideology of the day. The fact that it was announced in a large rally in a Thessaly village associated in public memory with peasant revolts against large land owners gave additional symbolism to the gesture.

Initial studies had been produced by the late 1960s and it should not escape attention that the first serious feasibility report by a Swiss company reached the conclusion that the implementation of the project for the purpose of irrigation would not yield positive economic results. In 1979 it was decided to commission the first large scale technical study and before the end of the 1980s the government was determined to implement the project (Giannakopoulos, Th., 1989). By the late 1980s and early 1990s work had started on a small scale but the project's feasibility was still in doubt, objections were raised, and demands were made to study first in depth the water economy of Thessaly and to assess environmental impacts. In 1991 a large number of environmental NGOs issued a joint statement against the diversion. However, in 1993 the central government signed a preliminary contract with a foreign construction consortium, which was never finalized.

In accordance with European and national law, the government approved the environmental protection conditions of the project but in 1994 the relevant ministerial decision was declared void by the Council of State following an appeal by four major NGOs, on the grounds that environmental impact ought to be assessed for the entire project and not separately for individual engineering works. A new impact study was carried out (ENVECO, 1995; Ministry for the Environment, Spatial Planning and Public Works, 1995) in a period of just few months to satisfy the court objections and the government proceeded to renewed contracts. It also reformulated the specifications of the project and adopted an option of reduced flow diversion, the so-called "partial diversion".

A new ruling of the Council of State in 2000 halted the process, this time because the protection of an historic monument had not been taken into account in the alternatives

considered in project planning. The government was forced to commission a supplementary impact study, but in 2005 a new appeal was upheld by the CoS because it took the view that the project was in breach of national legislation on water management. For the first time it took into consideration the EU Water Framework Directive of 2000 and ruled that a water management plan of both river basins, supplying and receiving water resources, was a prior requirement. With a second ruling of the same year, the court quashed the decision approving the environmental conditions of individual works of the project, on the grounds that the annulment of the conditions for the entire project carries with it the annulment of the conditions of parts of the project. The reaction of the government, through the Ministry for the Environment, was to enact in 2006 an amendment in the national parliament to enable the diversion (Ministry for the Environment, Spatial Planning and Public Works, 2006). In the meantime the dam and power station of Mesochora had been built and the dam of Sykia and the large water tunnel to Thessaly were well under way to completion.

Throughout this period protests were mounting, on the Thessaly side to speed up the process and on the Aetoloakarnania side to put an end to the project (Aetoloakarnania Prefectural Council, 1995; Aetolian Company for the Protection of the Landscape and the Environment, 1993; Lympouridis 1992a, 1992b and 1999; Technical Chamber of Greece / Regional Chapter of Central and Western Thessaly, 1986). The active involvement of NGOs was a notable feature, but even more remarkable was the mobilization of activist groups which sided with the Aetoloakarnania protesters, sometimes using strong language and unusual forms of action for an environmental cause.

Appeals against the 2006 legislation were not late to come. A main appeal was made against it which invoked the EU Water Framework Directive (European Union, 2000; European Commission, 2002). The Cos decided to postpone its decision and submitted a request to the Court of European Communities seeking advice on the implications of the directive for the project. But an appeal was also lodged seeking an interim injunction to halt the project. This time it was exclusively local governments and citizen organizations that either appealed or resisted appeal in front of the CoS. The appellants' claim was that all work should be suspended until the administration conforms with the 2005 court rulings. In this case too the court decided to postpone its ruling until a response is received from the Court of European Communities. Given that this may take a long time, it is difficult to forecast what will happen. The government which lost power in the October 2004 elections had commissioned a new environmental impact study on the basis of a further reduction of the flow volume to be diverted. The new government that came to power is rather prepared to postpone decisions and wait until the CoS reaches a final verdict and until all necessary water management plans for Thessaly are completed.[9] The Council of State ruled in February 2010 that all work should be discontinued for the time being.

The outcome is difficult to predict given the obstinate polarization of public opinions and feelings, with the two regional communities facing each other across the Pindus range. The politics of this contest will probably determine the end result. But at the same time the temporal dimension has already had its effect. Since the first promise of a water bonanza in Thessaly there has been a change of the dominant development paradigm, a decline of the fashion of gigantic engineering projects and a decisive rise of environmental consciousness.

d. The project

The purpose of this report in not to provide technical information and to describe the project works in engineering terms. Therefore we include here only a short paragraph on the subject. It must be noted however that the exact nature of the project has changed over the years, first because the volume of water flow to be diverted was reduced after the initial

[9] See newspaper reports (*Kathimerini*, 25.11.2009 and 12.1.2010; *Eleftherotypia*, 13.1.2010 and 18.1.2010; *To Vima*, 24.1.2010).

reactions, i.e. when the so-called "partial diversion" was adopted, and secondly because the official rhetoric has gradually shifted to sidestep the accusation that the project was aimed at providing irrigation for water intensive and wasteful cultivations, which ought to be scrapped as uneconomic, without embarking first in a total review of water management in the plain of Thessaly. The tendency has been to re-label individual dams and reservoirs as serving energy production objectives, rather than irrigation, and therefore as being in the responsibility of the Public Power Corporation and not of the responsible ministry (YPECHODE). Hence, individual projects described in the mid-1990s as integral parts of the overall project to divert water to the Thessaly plain were labeled 10 years later as purely hydroelectric ones. This creates a certain amount of confusion as to which construction works are part of the project.

With these reservations in mind, we provide the following brief outline description (Technical Chamber of Greece, 2005; ENVIPLAN, 2004). The diversion project includes two large dams in upper Acheloos (Mesochora and Sykia), smaller dams at Mouzaki, Pyli and Mavromati, reservoirs and hydroelectric power stations alongside the dams, a major diversion tunnel, 17,4 kms in length, linking the Sykia reservoir with the plain of Thessaly, a second connecting tunnel between Mouzaki and Pyli, an inflow conduit from Mesochora to Glystra (near Sykia), road works and an immense irrigation, drainage and water storage network over an area of 350,000 Ha, the construction of which, at least partially, is likely to be left for a later stage.

What is more important to stress, regardless of the technical characteristics of dams, reservoirs, tunnels and power stations, is that the long controversy over the project resulted in a constant redefinition by the government of the project's goals in order, on one hand to answer the objections of the Council of State, which kept issuing rulings overturning government decrees and decisions, and, on the other, to pacify and convince the objectors and the critics that the project was not necessary simply to perpetuate inefficient agricultural practices. The arguments being put forward were that the project was of course needed for irrigation (there was no way to deny this), but was equally essential for energy production, urban water supply and even environmental protection and improvement in Thessaly. It was argued at the same time that there was no danger of environmental deterioration on the side of Aetoloakarnania.

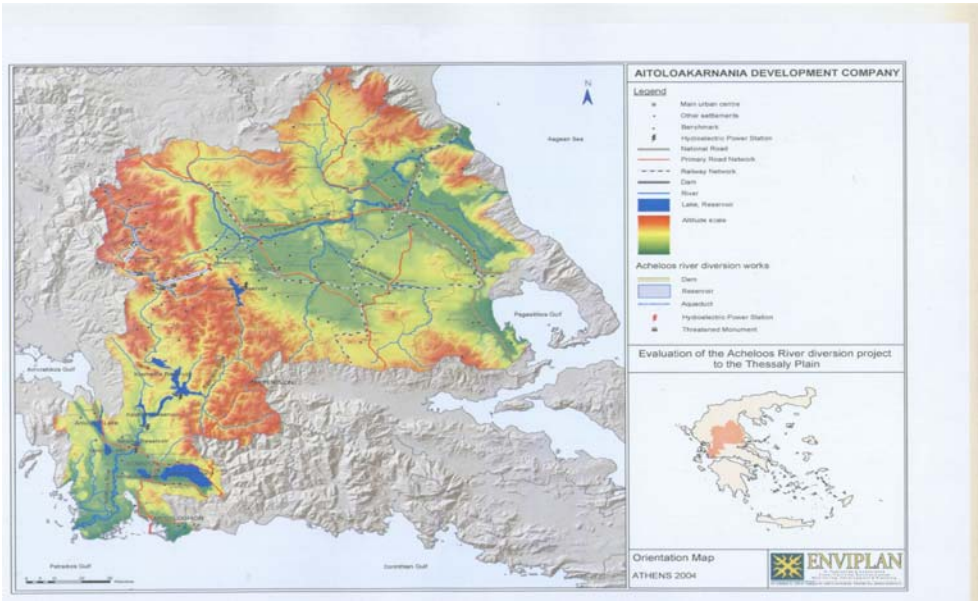


Figure 24: Map of the project area: The Acheloos river basin on the west and the Thessaly plain on the east of the Pindus range (source: ENVIPLAN s.a.)

e. Actors involved

The extent of the geographical area affected by the diversion project, the size of its population, the complexity, magnitude and cost of the project, the political and social interests involved, and the social dynamics that grew in the process, particularly in the last 25 years, explain the number of actors involved and the intricate web of their interactions. We attempt here to offer a simplified picture.

Central government

The first group of actors included the central government, its regional branches and government – controlled organizations, such as the Public Power Corporation, although the views expressed are not always identical. The most important actor in this group is the Ministry for the Environment, Spatial Planning and Public Works (YPECHODE), the life of which spans the entire period from the mid-1980s to the end of 2009. It is a central government ministry, where, according to its critics, the Public Works component was always its strongest section, and the "public works" mentality usually prevailed. Throughout this period, the central government as a whole and YPECHODE in particular consistently supported the realization of the project and denied its harmful environmental impacts, sometimes with a great deal of obstinacy and often resorting to legalistic tricks to overcome adverse court rulings. The most typical instance of this attitude was the sudden inclusion in 2006 of an amendment in an unrelated draft law then under discussion in the national parliament, which attempted to bypass previous Council of State rulings.

Important players were other central government ministries, such as the Ministry of Development (and the Ministry of Industry before that), the Ministry of Economy and Finance (and the Ministry of National Economy before that) and the Ministry of Agricultural Development and Food (formerly of Agriculture). They played a role through their responsibilities for water management, energy, public investment and farming. The autonomous Public Power Corporation, in charge of electrical energy production, controls all hydroelectric power stations. It objected originally on the grounds that the diversion of the river flow would affect the economic efficiency of its older power stations along the course of the river. Later however it concurred with the government decisions on the project.

Following the October 2009 national elections the distribution of responsibilities within central government structure was altered. For the first time, the political leadership of the new Ministry for the Environment, Energy and Climate Change (YPEKA), which now controls environmental, energy and spatial planning policy, appears hesitant in its support of the project in spite of the vast sums of national investment already expended on the project. The minister in charge of YPEKA, with a much stronger environmental profile than her predecessors, especially the minister of the period 2004 – 09, bides her time until the Council of State rules on fresh objections lodged in front of it and until water management plans are completed for the region of Thessaly. The ministry's special secretary for water management has stated that there is yet no clear evidence of Thessaly's real deficit in water resources. The minister of Agricultural Development also agreed that decisions must be postponed until the completion of management plans. On the other hand, the position of the new Ministry of Infrastructures, which is now in charge of public works, is ambiguous.

The position of regional authorities, i.e. of the General Secretariats of the regions of Thessaly and Western Greece, which are appointed by the central government, is, as expected, influenced by the public opinion of their area of responsibility. When the *perifereiarches* (heads of region) become directly elected by each region's electorate, which is expected to happen soon under an already announced reform, the chances are that they will be much

more adamant in their support for the views of the population of either Thessaly or Aetoloakarnania.

Local organizations

Local actors comprise municipalities and prefectures (1st and 2nd tier local government respectively), municipal and prefectural development companies, rural cooperatives, trades unions and producer chambers. Not surprisingly their views depend on their regional / local perspective. They have been extremely vociferous in their protests and have lobbied the government authorities systematically.[10] They have grouped into broader *ad hoc* agencies, as in the case of Thessaly, to maximize their impact. Given that on the whole central governments have been in favor of the diversion project, the priority of the organizations of Thessaly was to exert pressure to speed up the process or to intervene in court cases to lend legal support to the government. The first time they became really worried was when, after the October 2009 elections, clouds appeared on the horizon regarding the central government determination to press ahead with the project. The political clout of Thessaly exceeds by far that of Aetoloakarnania, hence the organizations of the latter had to rely on the moral support and the technical and legal resources of nationwide environmental organizations, especially in court cases. Given that the government had in its arsenal a number of technical studies favouring its objectives, the development company of the Prefecture of Aetoloakarnania commissioned a well known consultancy firm to produce an evaluation of the project (ENVIPLAN, 2004). This is an unusual step for local government companies, which are usually short of financial resources.

Attitudes are not going to change, when the current administrative reform alters the administrative map of the country. Elected prefects will be replaced by officials of the new elected regional authorities, which, as we pointed out, will probably follow the preferences of their voters. All other regional and local organizations will continue in their present positions, a situation which favors Thessaly for the reasons we explained and because of the power of its rural cooperatives and farming associations.

The Council of State

As in several aspects of social and economic life in Greece, the role of the Council of State (*Symvoulio tēs Epikrateias*), i.e. of the supreme administrative court, is crucial. Out of the rulings of CoS has grown a formidable body of common law on issues of environmental protection, sustainable development and spatial (urban and regional) planning. In the case of the Acheloos project, CoS involvement begins in 1994. Since then, either in its plenary court composition or through its 5th section, it issued 7 rulings, the last in December 2009, which have annulled a number of government decrees and ministerial decisions approving environmental impact assessments or ratifying construction contracts (CoS, 1994 – 2009). Appeals to the court were lodged by local authorities of Aetoloakarnania, citizen moverments and, what is most important because of their legal resources, by national NGOs. It is not possible even to summarize here the content of these rulings, but we can indicate the most important arguments on which they were based.

The court argument in the first resolutions rested on the principle that environmental impact had to be assessed globally, i.e. for the entire project and all its area of influence, and not for individual works, such as dams, reservoirs, tunnels etc. The ministry complied and commissioned a unified environmental impact study. A later court ruling admitted as justified

[10] See e.g. Technical Chamber of Greece / Regional Chapter of the Department of Aetoloakarnania, 2005, and the views of the Prefectural Council of Aetoloakarnania in www.aitoloakarnania.gr. For views on Thessaly's side see the position of the Panthessalic Coordinating Committee in www.kosmoslarissa.gr.

a complaint that the administration withheld information which according to EU legislation had to be freely accessible. Yet another ruling annulled the plan of the project because of failure to examine alternatives so as to save a listed monument (a byzantine monastery), as required by relevant international conventions and the Greek constitution. Finally, in its latest ruling, the court upheld an objection that a water management plan had not been prepared and approved in advance for the entire project area, as it should. The interesting point here is that this failure was considered not only in the context of Greek legislation, but also "in the light of the EU Water Framework Directive", in accordance with which the project had to be environmentally assessed with respect to the entire Acheloos river basin or, which is even more demanding, with respect to the entire "river basin district", which could potentially encompass both the Acheloos and Pineios river basins. Given the doubts regarding the incorporation of the directive in Greek law and other juridical questions, the issue was referred for clarification to the Court of the European Communities.

The CoS has become a sort of champion of environmental causes and it enjoys the appreciation of the ecologically sensitive public. For its detractors it has elevated itself to the status of a super-government. Given the frequent frictions between the CoS and the administration, politicians tend sometimes to consider it as an effective opposition to their policies. In 2006, the then YPECHODE minister was clearly in difficulty to conceal his anger over the rulings regarding the Acheloos diversion and spoke of the "incomprehensible stubbornness" of certain CoS judges (Ministry for the Environment, Spatial Planning and Public Works, 2009).

National environmental NGOs

Non-governmental organizations were the main movers of court actions to block government decisions. They were WWF Hellas, the Greek Society for the Protection of the Environment and Cultural Heritage, the Greek Ornithological Society and the Greek Society for the Protection of Nature. Apart from the legal procedural arguments they used in order to have the government decisions quashed by the courts, their position on the substance of the project was that they would be serious environmental damage in the Acheloos river basin as a result of it, that environmental deterioration in the plains of Thessaly is the result of chronic natural resource mismanagement and that its restoration could be achieved by wise management to stop the squandering and pollution of available water resources and by restructuring cultivations.

It is worth pointing out that the profile of NGOs as protest agents and as actors who can take practical action to prevent policies which are harmful to the environment is very high in the country. Alongside the Council of State they are frequently the object of the wrath of politicians, who view their attitude as approaching fanaticism and hypocrisy. In 2006, the same minister who inveighed against the Council of State accused "certain NGOs" for suffering from "ecological squinting".

The experts

The experts are a mixed group, of which the allegiance to a particular cause may be influenced by client relations. The experts however can be members of four distinct "communities", often simultaneously. They may be freelance professionals frequently commissioned as consultants to carry out studies on behalf of the administration or university professors and researchers, engaged in research or sometimes invited to write reports for the government or specialists with a definite ideological – political commitment or, finally, members of professional organizations and therefore involved in collective processes of passing judgment on particular issues.

In the long history of the Acheloos project, this diffuse group of experts had an important role in all these capacities. A large number of Greek and foreign consultants produced a record number of studies. Apart from purely engineering studies, private firms worked on environmental impact assessments or on evaluation studies. University committees or individual university teachers wrote reports, either independently or at the request of government. Professional organizations organized conferences, published proceedings or formed committees of experts who prepared evaluation reports. Individual experts offered their professional opinions and lent support to political party positions and worked in party committees.

In the Acheloos case, putting aside consultancy work commissioned and paid by the central government, the balance of expert opinion was against the project, although there have been exceptions. When the Techical Chamber of Greece organized in 1988 a conference on the Acheloos diversion, its president pointed to the lack of a global study of the needs of Thessaly (Technical Chamber of Greece, 1993a). As early as 1995, an independent university committee expressed grave reservations regarding the knowledge and information base on which the project relied at that stage (National Technical University of Athens, 1995). Individual university professors specializing in water management have been strongly critical all along, even as late as 2009 (e.g. Mylopoulos 2007 and 2009). An evaluation study produced in 2004 by consultants, on behalf of a local government company of Aetoloakarnania, concluded with a long list of technical and legal deficiencies of the project, which it considered as clearly harmful for the environment (ENVIPLAN, 2004). However a report compiled in 2005 by a working group of the Technical Chamber of Greece (TEE) was sympathetic to the project (Technical Chamber of Greece, 2005). The Thessaly regional division of TEE was naturally in agreement, but the Aetoloakarnania division was sharply against.

Political parties and politicians

Given the wholehearted support to the project given by successive governments since 1984, when its realization was first promised to the people of Thessaly by the then Prime Minister, it is not surprising that the two major political parties (Panhellenic Socialist Movement or PASOK and New Democracy Party) which have alternately occupied power during this period are in agreement with the project. As we mentioned already, the first cracks within PASOK appeared after the 2009 elections. But even today it is clear that within the major parties there are diverging opinions, which means that these parties are not single actors speaking with one voice. Individual politicians are influenced by the voters of their constituencies, which becomes amply evident when for instance a politician elected in Thessaly occupies a crucial ministerial post. Minor parties are not in agreement on the issue of the project. E.g. parties of the political left seem to disagree among themselves, which was already evident when the project was still in its early stages in the late 1980s.

Local societies and movements

The attitude of local organizations and of national political parties is, as expected, dependent on the interests of local societies, which can be seen as important actors. This is particularly true when the local society, as in the case of Thessaly, has shown exceptional cohesion because of the structure of its rural economy, reflecting the rather erroneous perception of the farmers that they constitute a distinct and compact social class. Inevitably the issue becomes entangled with the pattern of claims perennially made by the farming community, which finds itself in a constant decline and identity crisis and sees government subsidies as the only solution to its problems. The farmers of Thessaly are well organized and the

defense of their economic interests takes regularly an extremely aggressive form. It is not insignificant that the completion of the diversion project was among their claims when they blocked all national highways in 2010 to press the government over other issues and claims, an action which is repeated practically every year.

Publicity poster for a protest rally against the flooding of the village of Mesochora

Acheloos river near the Kremasta dam (Source: http://viso.jrc.ec.europa.eu/wfd_prb/info/Site_Acheloos_Greece.PDF)

Figure 25: Publicity poster and photo from Acheloos river

Another occasion, when the Acheloos project has led to intense local mobilization and protest, is the case of the mountain village of Mesochora which is due to be flooded when the Mesochora reservoir is filled with water. Local protests either in the village itself or in Trikala, the capital of the prefecture of the same name, were emotional and attracted national, even international, attention (Ganias, 2008). Local associations were among the objectors in court cases. *Ad hoc* nationwide movements of activists have espoused their cause in a very aggressive manner and a great deal of publicity. Of course, the political power of this village community cannot be remotely compared with that of the farmers of the plain.

European Commission

The European Commission has systematically remained aloof of this process. This is surprising given the size of funds channeled into Greece during the last 25 years under the EU Structural Policy. The EU decided at an early stage not to co-finance the project, although it had funded some minor work at the beginning, probably because feasibility studies it commissioned showed that the project was uneconomic. It intervened at some point to challenge the legality of contract awards to construction companies, but on the whole kept its distance. Thus an actor of the EU importance has not played an active role in spite of the unusual size of the Acheloos project.

Nevertheless, the policies of the European Union may have a decisive effect on the process of the project, which has nothing to do with its planning, implementation and funding. The EU Water Framework Directive may determine not only the attitude of the Council of State

after the latest appeal, but may also modify the entire conception of the appropriate national policy to tackle the problem of water resources in Thessaly, thus placing the Acheloos project on a new footing.

Construction companies

The construction companies executing the project are no doubt important "behind-the-scenes" actors, whose role however it is extremely difficult to assess. They are very careful to avoid public controversy and are even reluctant to intervene openly in court cases.

Media

Last, but not least, of the actors that have played a role in the history of the project is the media. Naturally they do not have a uniform attitude, but they have given great prominence to the issue, with a constant stream of reports. There are of course newspapers which champion environmental causes and have maintained a critical stance all along. It is not surprising that the local press, either in Thessaly or Aetoloakarnania, has supported the views of their readers.

Consumers and taxpayers

The national consumer and taxpayer is not directly involved in the controversy and the shifting of costs, risks and vulnerabilities. But he / she bears the cost of agricultural produce when it reaches the shelves of super markets and greengrocers and shoulders the cost of the construction projects. Hence, since our interest is to look at the way vulnerability is transferred from one group to another, he / she cannot be left out of the picture.

We present the configuration of actors involved in the following figure:

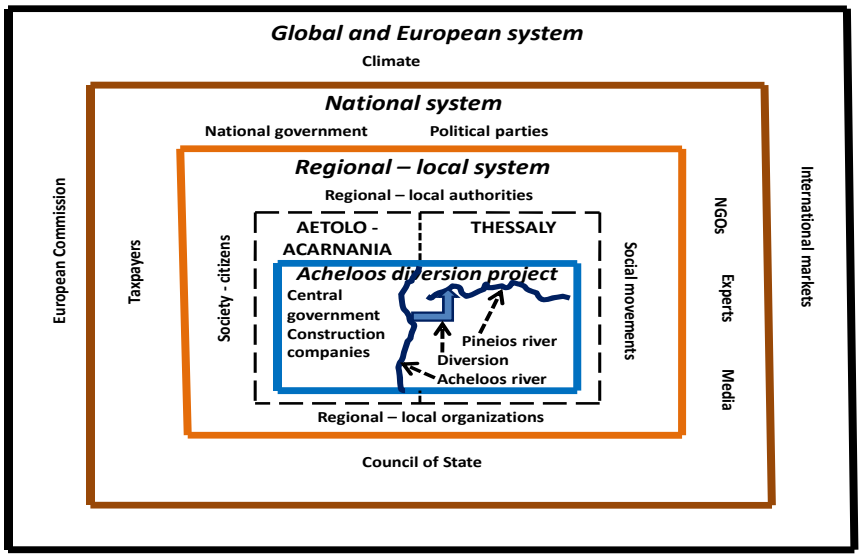


Figure 26: Acheloos diversion project: The actors involved and affected

f. Potential risks and nature of vulnerability

At first sight, the nature of vulnerability is mainly economic on the side of Thessaly and environmental on the side of Aetoloakarnania, but the situation is more complex than this simple statement. For the farming community of Thessaly the main risk is drought and water

shortage, which presents a direct threat to cultivations. Hence they perceive their problem as one of vulnerability to drought. They point to depletion of water resources in surface and underground water bodies, to declining soil quality, soil erosion, subsidence and symptoms of desertification. Drought however is not defined only in meteorological terms and as a function of lower rainfall. It is also a function of water use and of management of available water resources. As critics of the project are quick to remark, there has been gross mismanagement in the past, which continues unabated, while agricultural land is being used for water – intensive cultivations, e.g. cotton growing, which is not a wise practice. Uncontrollable tapping of underground aquifers has led to a dramatic lowering of the water table and water salinization. Excessive use of chemical fertilizers has polluted surface water, especially that of Pineios river, the main river of Thessaly, into which water from Acheloos river is planned to be diverted. Thus, it is true that environmental vulnerability has been added to economic one.

Vulnerability in the Acheloos river basin is first and foremost environmental.[11] The river flow has been repeatedly disturbed by damming for the purpose of hydroelectric power production. Three large dams and reservoirs have been built in the past on the main course of the river, in addition to one more on the course of an important tributary. Depriving the riparian ecosystem, especially in the river delta and its shallow wetlands, of a vast volume of water which will be diverted to Thessaly threatens to cause irreparable ecological damage (Vasilakis, 1999). Biotope degradation, landscape destruction and obliteration of flora and fauna will probably be the result, although it must be admitted that there are diverging scientific views on the subject. The official government position is, or at least was until recently, that sufficient flow will be maintained to avoid environmental effects. However, if the pessimistic predictions are correct, environmental vulnerability is likely to generate economic vulnerability as well. This is due to the prospects of eco-tourism and of fishing and fish growing activity in the lagoons of the delta, which are bound to suffer. But adverse effects are likely to occur too in areas where restructuring of agricultural production was already a pressing necessity because of the sharp decline of traditional cultivations, such as tobacco growing. Resident livestock breeding, which is a sector of some potential, will also be affected.

The threats the entire project area (both Thessaly and Aetoloakarnania) is facing include drought (see the map below), declining precipitations, ecological degradation and decline of quality of environmental flows, all exacerbated by the process of climate change. The latter's impact is well documented in EU reports (Commission of the European Communities, 2008 and 2009); European Commission, 2009), but also in reports produced by a variety of Greek research centres and advisory agencies on the impacts in Greece (National Observatory of Athens, 2005; WWF Hellas,2009; Akylas, Lykoudis and Lalas, 2005; Giannakopoulos, C., 2009; Economic and Social Commission of Greece, 2008b; Wassenhoven *et al.*,2009). In the last few years the effect of climate change and its implications for the Acheloos project has been repeatedly stressed by experts as evidence mounts that there will be important impacts on the amount of water reaching the river basin (Mylopoulos, 2007; Mylopoulos *et al.*, 2009). There are already indications of a reduced flow. There is therefore an open question regarding the contribution that the river can make in the future to the water economy of Thessaly. The magnitude of the task is such that elementary respect to the precautionary principle should at least make policy makers more cautious.

If concerns for the future of the Acheloos catchment basin, its mountain hinterland and its estuary are justified then we have a clear case of the vulnerability of the farmers and the

[11] See Greek Ornithological Society, WWF Hellas, Greek Society for the Protection of the Environment and Cultural Heritage and Greek Society for the Protection of Nature, 1994(?).

agricultural economy of Thessaly being transferred to Aetoloakarnania, through the diversion (*transvasement*) of the river. In essence this is the issue at stake. As long as the technical arguments remain unresolved and the affair degenerates into a political *bras de fer*.and a perplexing legal confusion, each side can draw its arguments from different professional studies and expert opinions.

The investment so far in money, political prestige and institutional credibility has become so large that we can also speak of institutional vulnerability in the sense that the country's decision making system loses its authority and suffers blows to its competence. The time dimension we mentioned earlier is critical. By pressing ahead with the project, the state is perhaps trying belatedly to answer yesterday's questions and remain faithful to obsolete ideologies. Even in terms of technical knowhow the ground has moved under its feet.

In the last 25 years there has been a cycle which was not marked by individual disastrous events (although certain minor manifestations have been reported, e.g. subsidence incidents) but by a rising shortage of water resources (itself a relative term) in Thessaly. *Perceived* economic and social vulnerability (perception is critical) has fuelled a cycle of influences and feedbacks, through the agency of official and unofficial institutional actors. Adaptation to perceived vulnerability demanded the use of natural, economic and political capital to mitigate vulnerability over a long temporal scale, marked by advances and retrogressions, power struggles and endless judicial litigation. But in the meantime the scene had changed and the values of the scientific community have themselves changed.

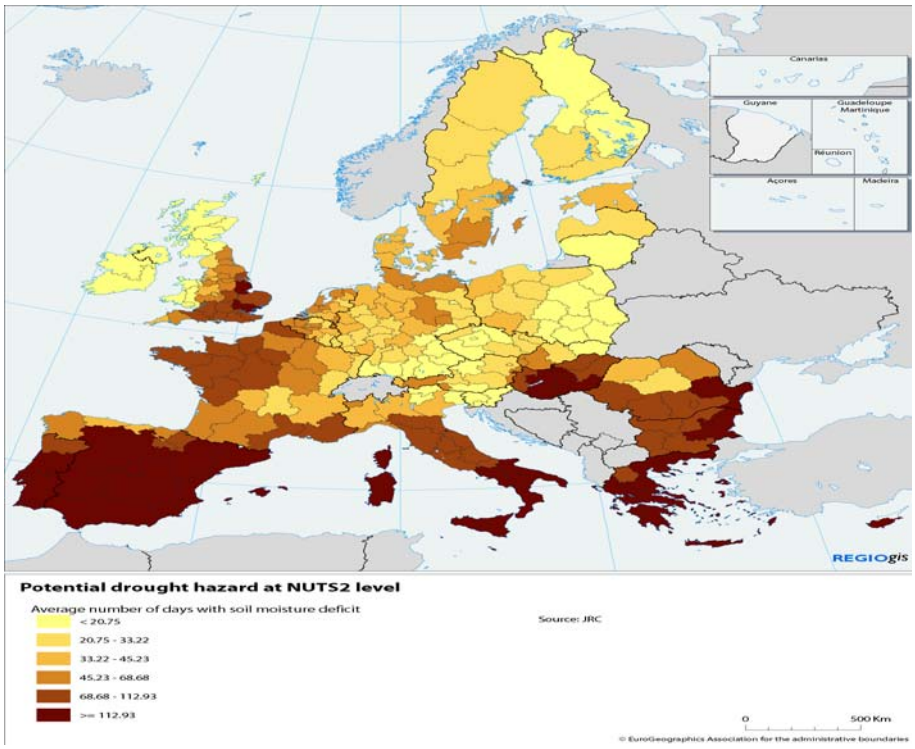


Figure 27: Map showing the potential regional drought hazard, 1958 – 2001 (Average number of days with soil moisture deficit), Source: Commission of the European Communities, 2008.

An extremely complex eco-human system is involved in this case, but there is clearly an ecological system (that of the Acheloos river basin) which is called upon to provide the natural capital for the mitigation of risks to which the farming community of Thessaly is

exposed. The opposing argument is that the natural resources necessary for risk mitigation and vulnerability adaptation exist within the territorial entity of Thessaly itself. We can speak here of a slow (real and potential) disaster cycle, triggered by a growing process of drought, affecting two territorial and eco-human systems, at the interface of which the diversion project is placed. But conceptually both the issues and the answers are now seen in a different perspective.

The case of the Acheloos diversion revolves around the interaction of macro-scale vulnerability actors, who include social groups, urban and regional communities, economic sectors on all scales, a variety of institutional actors from the European down to the local scale, civil society organizations etc. Local vulnerability actors are also present in this interplay, given the local impact of some of the project components. What is now being recognized is that there is a broader socio-environmental context the vulnerability of which has been neglected and remained unappreciated. To appreciate it properly demands a fresh look at the whole problem and the recognition that attention to fragmented vulnerabilities ought to give way to the vulnerability of a more global social and environmental system.

In the following diagram we attempt to show the interplay and transference of vulnerabilities in the Aetoloakarnania – Thessaly system.

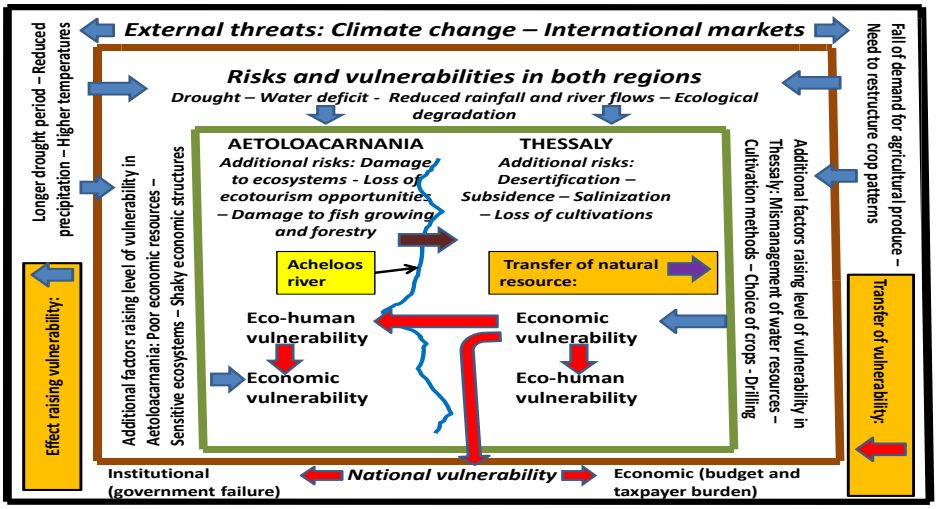


Figure 28: Interplay and transference of vulnerabilities

To understand the interplay of vulnerabilities we must highlight some broad features of the areas involved.[12] Aetoloakarnania is a relatively undeveloped and poor area of Greece, of which the agricultural population approaches 50% of the total. It is also an area of great ecological value. Three out of Greece's 11 wetlands protected under the Ramsar convention are located there. The Acheloos delta is one of them. The delta is in addition protected under the EU Bird Directive and as a NATURA area. Its wetlands are home for a large number of species, provide employment to fishermen and pisciculturalists and offer valuable tourist and leisure services. The lagoon system of Messolonghi is the second largest in Europe. The environment of Aetoloakarnania is particularly noted as a bird biotope. More than 270 species have been recorded. The river, which provides fresh water to the lagoons,

[12] We consulted the Development Plan of the Programming Period 2000 – 2006, the National Strategic Reference Framework 2007 – 2013 and the Regional Frameworks of Spatial Planning and Sustainable Development of the regions of Western Greece and Thessaly.

flows between them and another ecological site of great value, the forest of Fraxos, designated as a nature monument.

Regional operational programmes and planning studies agree that the future development of Aetoloakarnania requires a careful rural development and countryside policy and the promotion of alternative forms of tourism, such as eco-tourism, agro-tourism and cultural tourism. Ecological trails should be developed to provide access to its rich ecological sites. Livestock, fish and biological farming are also among the priorities. The problem is that water, especially that of Acheloos, is a crucial parameter. Although opinions are divided on whether the water surplus which will be diverted to Thessaly will ruin Aetoloakarnania's ecological assets, it must be pointed out that those who argue that this surplus is wasted anyway are mostly the officials and consultants of central government. It is worth pointing out here that tourism is particularly sensitive to climate change (Ehmer and Heymann, 2008; Economic and Social Commission of Greece, 2008a; Wassenhoven *et al*., 2009) and that the added effect on the flow of the river may have a serious detrimental impact on eco-tourism.

Agriculture is dominant in the economy of Thessaly, with a share of over 20% of economic activity. This share is especially high in the prefectures of Karditsa (30%), Trikala (21%) and Larisa (21%). As indicated in relevant studies, among the problems of agriculture in the region are the quasi-total dependence on cotton growing, the absence of products that are likely to be in demand in the future, such as bio-products or crops with a regional brand, the low percentage of irrigated land, water deficit, uncontrollable boring of aquifers and negligent use of water. It is remarked in the 2000 – 2006 regional operational programme than in spite of all warnings the cultivation of cotton and cereals kept growing in the last years of the previous century and that the first priority is the introduction of cultivation methods which are less wasteful of natural resources, especially water. The corresponding programme for the period 2007 – 2013 again stresses the waste of water resources and the pollution of water tables. The protection of natural resources is again among the priorities. To make things worse prices of agricultural produce have collapsed in 2009, with the price of industrial cultivations, such as cotton, falling by a staggering 38%.

The real cost of the project is a matter of defining what individual works are essential for its completion. The tendency of the government was to ascribe parts of total expenditure to hydroelectric projects and play down the cost of the irrigation project. A current estimate of the project's critics is that the total may end up higher than € 1,5 bn, which in the present fiscal crisis is unimaginable, given that the project is funded out of the national budget, i.e. by the taxpayer. The question therefore is really how to minimize losses. As a commentator aptly put it, "on the road to loss, if you stop you stand to gain".

This brief analysis shows that the main economic vulnerability actors are the farmers of Thessaly, a variety of producers active in fishing, tourism, forestry and animal husbandry in Aetoloakarnania and the national treasury, in fact the Greek taxpayers. The main eco-human actor is the environment of Aetoloakarnania, given that the balance of opinion is that the environment of Thessaly should be rather redressed by a wiser management of the region's own resources, which are presently squandered. Besides, the current international consensus is that environmental and water management should be undertaken and secured within each river basin and that entire catchment areas should be the focus of study (European Union,2000; Abel *et al*., 2002; Forslund *et al*., 2009). The main institutional actor, which stands to lose credibility and prestige, is central government.

The conclusion is that the Acheloos project, on the most reliable evidence so far, is a gigantic case of vulnerability transference particularly from the farmers and the agricultural

economy of Thessaly to the eco-human system of Aetoloakarnania and to the taxpayers. This seems to be a fair judgment of the situation, in spite of the arguments of central government (at least until recently) and of the technical studies it has commissioned ("client-oriented" studies according to one expert).

6.1.2 Micro-scale analysis of vulnerability actors: the case of flooding and chemical spillage in St Bernard Parish, New Orleans, Louisiana, USA following Hurricane Katrina in August 2005

a. The vulnerability actors

This section is a case study of the 'vulnerability history' of two closely inter-related 'vulnerability actors' in the communities of Chalmete and Meraux which are located in St Bernard Parish a few kilometers east of the centre of greater New Orleans, in Louisiana, United States (Figure 29). These vulnerability actors are:

a) the local parish population (i.e. residents, business owners, employees); and

b) the Murphy Oil Corporation (oil refinery owner and operator, employer).

Many other actors were involved in the flood and chemical spillage disaster, including the US Army Corps of Engineers (USACE) (the agency which constructed flood surge levee systems designed to protect the communities and New Orleans); local levee boards (who own and are responsible for maintaining levees); the Federal Emergency Management Agency (FEMA) (responsible for pre-disaster planning and disaster emergency response); and the US Federal Government (which provided financial aid to other actors). NGOs and volunteer organizations also appeared in the emergency relief period. In the flood disaster, institutional vulnerability (defined here as '*the potential for loss and reduced capacity to recover caused by the exposure of individuals, communities and local economies etc. to the uncontrollable adverse consequences of the critical shortcomings of institutions or institutional arrangements',* (ENSURE Deliverable 2.1)) was widespread, including USACE and FEMA, and extending to the White House and to the Federal Government's National

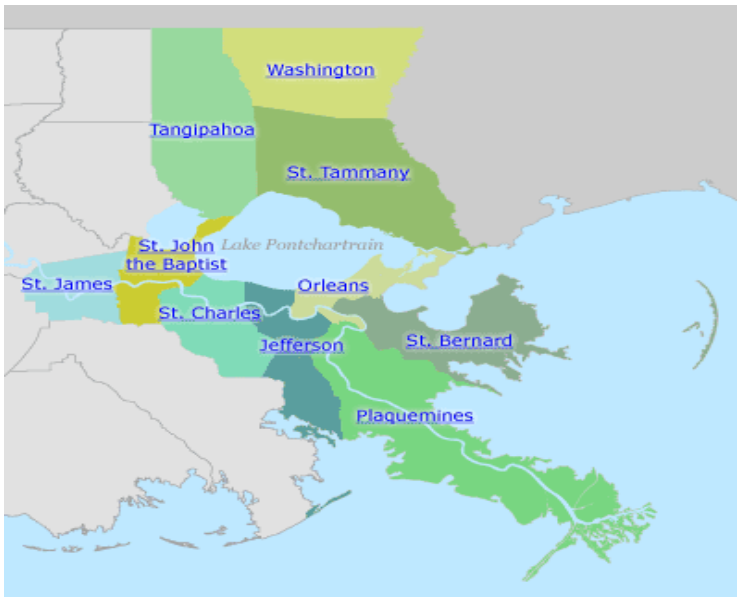


Figure 29: Location of St Bernard Parish and the ten parishes of New Orleans

Emergency Response Plan (US Congress, 2006). Therefore, although this case study focuses upon just two actors, it would be feasible to undertake a much more extensive case study analysis focusing on these other vulnerability actors. We found that it was desirable to analyze two rather than a single actor because it is difficult to explain one actor in isolation from the other.

b. Hazards profile of St Bernard Parish

St Bernard Parish is at risk of pluvial, fluvial and tidal surge flooding as a result of hurricanes. The parish is constructed on the deposited sands of the Mississippi delta and is only just above sea level. The parish was flooded during the infamous 1927 fluvial flood. During the 20th century the New Orleans region was been extensively flooded during hurricanes on at least six occasions, the last time before Katrina being in 1969. In the 1980s the USACE constructed a system of levees to protect New Orleans, including the parish. The parish is protected to about the 100 year design standard by levees which are an integral part of a New Orleans wide levee system. Despite the history of previous flood and hurricane events, prior to Katrina, most members of the local community believed that the likelihood of damage to their property from flood was so low that they were not at all worried about its occurrence.

The environmental scorecard for St Bernard Parish for January 2010 (www.scorecard.org/env-releases/county.tel?fips_county-code=22087) identifies it as one of the most polluted places in the USA owing to sequential toxic chemical releases by the oil industry which is well established in the parish, and in the Gulf of Mexico more generally. Health risks stem from toxic releases to both air and water. Cancer risks are rated as high. The pollution is not only a recent phenomenon: the published record of toxic releases in the parish goes back into the 1980s. There have also been a number of fires at the oil refineries necessitating evacuation of residents, and there has been a perceived risk amongst inhabitants of explosion and terrorism.

c. Population profile of St Bernard parish

Prior to Katrina, St Bernard parish comprised about 66,000 people: 51.7% female; mean age 37.07 years; 88.3% white, 7.6% Black or African American, 5.1% Hispanic or Latino (www.epdodunk.com/cgi-bin/popInfo.php?locIndex=3566). The parish comprised eleven communities, two of the largest being Chalmete and Meraux. Within St Bernard parish there is a strong clustering of racial and ethnic groups into communities. For example Chalmete and Meraux are predominantly white, whereas the St Bernard community neighborhood is predominantly black (97.8%) (www.gnodcd.org/orleans/4/26/people.html). Prior to Katrina, 23.4% of St Bernard parish were recognized as having a disability related either to transportation, employment or self-care (National Organization on Disability, 2006). The community is a relatively poor, blue collar one with below average mean annual incomes for the USA.

d. The flood and chemical spillage disaster

The timeline of events associated with hurricane Katrina is shown in Table 13 New Orleans benefited from the national hurricane warning system which predicted the timing and location of the hurricane's landfall, and also the hurricane and tidal surge severity. Mandatory evacuations were ordered for St Bernard's parish about 19 hours before flooding there, although a voluntary evacuation was advised 45 hours in advance.

The hurricane warning system and the evacuation plans for New Orleans afforded a potentially very important degree of resilience. Most people reduced their vulnerability from its potential maximum to a lower level by evacuating. St Bernard parish was under water for about 4 weeks after the event.

This is a case study of a very severely affected community with a long-lasting and on-going disaster recovery and reconstruction. The communities were affected by the high winds and sea surge flooding produced in 2005 by Hurricane Katrina (see - http://www.nola.com/katrina/graphics/flashflood.swf) and also by a subsequent major na-tech event comprising a very large chemical spillage triggered by the flooding (Figure 30). The Figure map shows the features of storm surge during and following the hurricane. Pink and blue shading indicates areas that flooded; blue-striped areas are wetlands. Stars indicate levee breaches or distressed levee areas; circles indicate pumping stations. Flooding was caused by levee failure and overtopping, with the levee failure causing a dam-break type flood (i.e. a high velocity flood) which drowned many of those who had chosen not to evacuate, or had not been able to evacuate, prior to the surge. The case study is also referred to briefly in Deliverable 2.1.

Table 13: Timeline of events associated with and following hurricane Katrina, 2005 in so far as they affected St Bernard parish)

Date	**Event**
2005	
August 24	Storm in Bahamas upgraded to Tropical Storm Katrina
August 25	Federal Emergency Management Agency (FEMA) Coordination Centre activated
	Governor of Louisiana declares state of emergency
August 26	National Hurricane Center forecasts that hurricane Katrina will strike east of New Orleans
	Katrina upgraded to Category 3 hurricane
	Mandatory evacuation order given to some New Orleans communities. St Bernard Parish given voluntary evacuation advice
August 27	Katrina upgraded to Category 4 hurricane, then to a Category 5 hurricane 6 hours later
5.00am	Mandatory evacuation order for all New Orleans ordered, New Orleans Superdome identified as the shelter for those with special needs
9.00am	Hurricane Katrina makes landfall just east of New Orleans
August 28	St Bernard parish flooded when levees overtop and breach in a dam-break type flood. 26,000 homes severely damaged or destroyed 15 public schools, 5 Catholic schools and one private school destroyed.
August 29	Governor of Louisiana orders evacuation of the whole of New Orleans including those in the Superdome
August 31	City of Houston opens shelters for evacuees
	Oil spillage discovered by Murphy employee at Meraux refinery
September 2	Murphy commences clean-up. c.3,000 now present in community.
September 3	Hurricane Rita. Evacuation ordered.
	Health risk advisory issued in St Bernard parish
September 21	Evacuees begin return to find dead bodies
November 9	Property by property oil contamination monitoring begins
November 14	
December 9	
2006	
January	FEMA brings in trailers (mobile homes) for evacuees to live in

	Murphy pays out $150 million in clean up and settlement costs with some residents
July	Streetlights and sewage system in Chalmete reported as not working; some houses under repair; residents living in trailers in their front drives. Population reported to be 20,000 by day but only 8,000 to 10,000 by night. One school open but many still closed and heavily damaged. About 300 of 1400 businesses reported to have re-opened for business.
August	
September	FEMA agrees to free demolition of thousands of homes
2007	
January	Outcome announced of Class Action legal case against Murphy by residents. Murphy found negligent. Process for paying out financial compensation commences
August	Population of St Bernard parish estimated at 23,420 (compared with 66,000 before Katrina)
2008	
March	Murphy submits planning application to expand oil refinery on land bought-up from residents after oil spill; anger amongst residents
August 30	Hurricane Gustav. Evacuation of St Bernard parish, USACE managed to prevent major overtopping of the levees. Street lighting now restored. Some trailers reported being removed. 8 new state-of-the-art technology schools reported as constructed, construction of 4 more public schools underway.
	17,000 homes reported to be in various stage of rebuilding.
2009	
March	Catholic school demolished. Reconstruction of homes, schools, churches is on-going.
	Population of St Bernard Parish estimated at 33,000 (compared with 66,000 before Katrina)

Source: Eisemann et al., 2007; numerous internet sources

St Bernard Parish, in which Chalmete and Meraux and also Murphy Oil Corporation's oil refinery are located, was flooded to a maximum depth of 4.3m when the storm surge from Hurricane Katrina caused the Mississippi River Gulf Outlet levee to fail. The oil refinery, as well as a neighbouring one, is located in the 100 year floodplain. One of many oil storage tanks was dislodged during the flood event releasing over 1 million gallons of mixed crude oil contaminating 1,700 homes in Chalmete and Meraux. The oil spillage was the worst residential crude oil spill in America. In the years prior to Katrina, these communities experienced a series of emergencies caused by the oil refineries, including a fire and various chemical spillages, but none were of the magnitude of the Katrina disaster. Over 150 members of the communities died as a result of the flood disaster which caused major damage to homes and businesses. About half of the population has now returned to the communities but, although others are reported to want to return when conditions have improved sufficiently, the community remains about half of its pre-Katrina size. The chemical spillages caused enormous added anxiety and uncertainty amongst residents about the potential immediate and long term additional health effects and additional effects on property values, as well as subsequently sparking off continuing anxieties about the risks associated with the continuation and expansion of oil refinery and storage operations at this site. Most of the home sites were cleaned by Murphy and placed back into residential use.

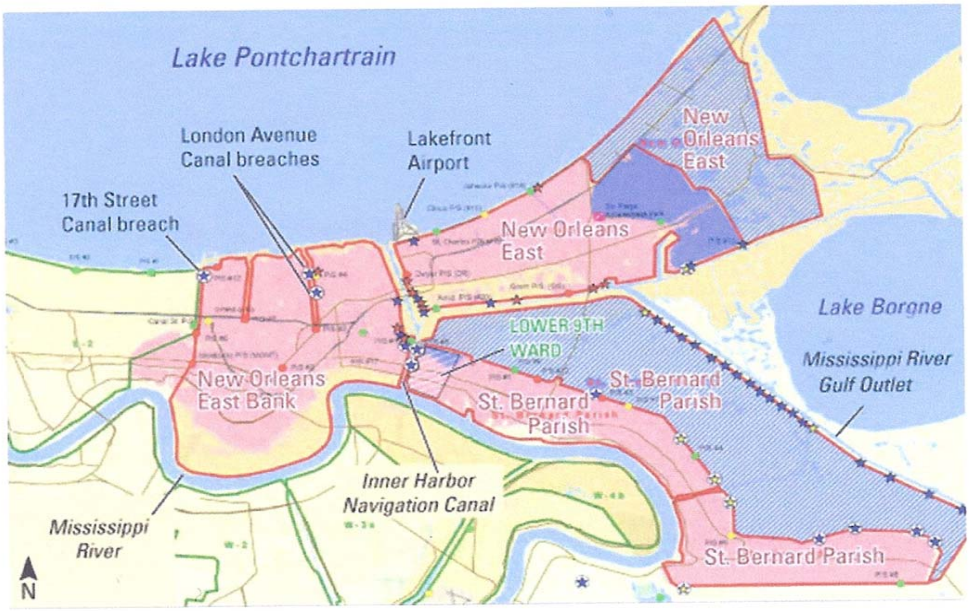


Figure 30: The New Orleans hurricane protection system and the location of St Bernard Parish. Source: National Academies Press (2009).

However, properties in four roads were given an option to participate in a Murphy property buy-out program. The combined flood and chemical spillage disaster caused enormous disruption to lives, work and social networks in the aftermath. To the considerable despair and stress associated with the flood and oil damage, the residents have had the added stress of enduring conflicting advice, an FBI investigation into fraudulent reconstruction contracts, a major court action and prolonged environmental monitoring. All of this is likely to have adverse health impacts. Although a clean-up operation has taken place, dangerous residues may have seeped into the soil. Many were not insured for flood damage (www.corpwatch.org.article.php?id=13016). Many of those residents who have decided not to return to the neighborhood, with its visibly abandoned homes and slowly improving infrastructure, feel that the neighborhood has been lost as a community and that their roots have gone (www.truthout.org/article/3330-million-settlement-deal-katrina-oil-spill).

Following a major court action against Murphy, in January 2007 plaintiff residents were awarded 330 million (US$) (i.e. 486 million Euros) financial compensation for negligence. The post-disaster adaptation period can be divided into (a) the 18 month period from August 2005 when the disaster occurred until January 2007 when many of the residents were awarded financial compensation, and (b) the period after January 2007 when the financial compensation began to be paid and the positive effects of this on people and the community began to be felt.

e. Vulnerability actor analyses

Tables I and II in Appendices summarise the pre-disaster vulnerability, actual vulnerability and post-disaster vulnerability of both actors at the focus of this case study. This analysis considers both flood and the na-tech threat and disasters. Tables III and IV in Appendices identify the resources committed by each actor in the pre-disaster adaptation and post-disaster response.

Allocating a simple 'no change', 'reduction' or 'increase' descriptor to the cells in Tables V in Appendices onwards proved to be difficult, and so all Tables from Table V in Appendices onwards describe the impact in each cell. In some cases, as indicated, the impact is

complex. Tables V and VI in Appendices summarise the internal rebalancing of vulnerability in the pre-disaster adaptation and post disaster response periods. In completing the tabulations, it sometimes proved difficult to distinguish clearly between the information taken into account for particular facets, and some facets appeared not to be particularly applicable. For example, in Table VI in appendices, it proved difficult to make a distinction between post-disaster, social and systemic facets – both relating to social capital. Also in the same table, the institutional facet was difficult to interpret in a meaningful manner. Table VII in Appendices analyses the internal redistribution of vulnerability to the disaster stages and to new hazards by a) the local population and b) the oil company.

Table VIII in Appendices attempts an identification of the transfers of vulnerability to other actors by Murphy Oil Corporation. Here it is necessary to clearly define what is meant by a 'transfer of vulnerability' and to distinguish such transfers from the 'creation or extension of vulnerability'. Given that in Deliverable 2.1 vulnerability was defined as 'susceptibility to loss, or potential for loss, and by the capacity to recover', transfers of vulnerability might be defined as 'successful attempts by one vulnerability actor to externalize (i.e. to push onto another actor or actors) its potential losses and the provision of resources to allow it to recover'. This is different to the circumstances in which say, an actor (e.g. a community) is placed in a position of vulnerability by the actions of another actor (e.g. an oil company), although some kind of 'transfer' (i.e. an extension of vulnerability from one actor to the other, but not a swap) also seems to be involved. Table VIII in Appendices seeks to distinguish between 'transfers' and 'extensions' of vulnerability, although distinctions are sometimes difficult to make. A similar, parallel, analysis could be undertaken to identify transfers of vulnerability by members of the local population. In Table VIII in Appendices the post-disaster response period is divided into short and medium term periods because transfers began to alter (i.e. they reversed) after January 2007 as a result of the court action. Tables VIII and II in Appendices allow 'switches' in the direction of vulnerability transfer to be identified. Prior to January 2007, most of the transfers identified operate in the direction of Murphy externalizing damages and costs onto other actors including the local community. However, after the ruling of the court case in January 2007, many members of the local population began to receive financial compensation for the losses which they suffered as a result of Murphy's negligence. This will have substantially reduced financial deprivation (an important component of economic vulnerability) and may have gone some way to a) reducing anxiety and stress from then on and, in some cases, may have been b) a way of compensating for disruption to lives in the 18 months after the disaster

f. The altering balance of vulnerability of the local population

This case study reveals that through the pre- and post-disaster periods, vulnerability underwent changes in type (from potential for stress, to potential for loss, to loss, and to incapacity to recover); in degree (i.e. the depth of vulnerability); and in balance (i.e. who carries the vulnerability, and the mix of different facets of vulnerability).

Figure 31 is a representation of the rebalancing of vulnerabilities of both Murphy Oil Corporation and the local parish population over the course of the August/September 2005 flood and oil contamination disaster, through each of its phases. The last phase is entirely conjectural and portrays how vulnerabilities may return to close to their pre-disaster balance when the disaster is taken out of the context of vulnerability to a further disaster (which was present from early in the emergency relief phase). The change in the fortunes of members of the local population following the court case which found Murphy negligent is an example of how financial deprivation (i.e. economic vulnerability) lessened considerably for many following the period between the disaster and this court case when financial deprivation was major issue. However, social vulnerability continued to be a deep problem because of the

impossibility of replacing those who lost their lives, and those who resettled elsewhere or who have not yet returned. This is one example of a major rebalancing of vulnerability of the local population. Economic and social vulnerability were both deep, but economic vulnerability began to decline more rapidly than social vulnerability as a result of the legal settlement. In reality rebalancing was occurring almost continuously throughout the disaster cycle. Murphy was less vulnerable than the local population throughout. As rebalancing occurs over time, this subject is further examined in 4.0 below.

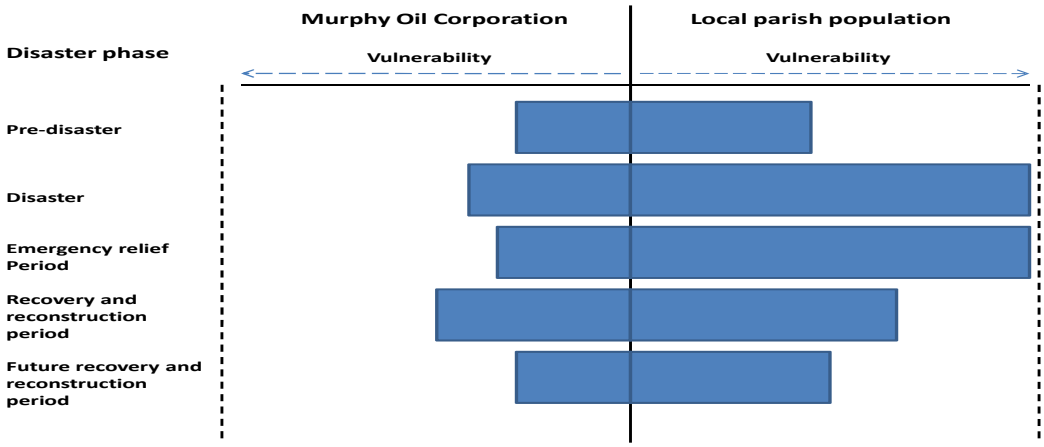


Figure 31: The changing balance of vulnerabilities between two vulnerability actors over the course of a single disaster cycle (not taking into account the vulnerabilities arising from the risk of a further disaster)

Table 14 below shows the distribution of identifiable vulnerability transfers by Murphy Oil Corporation to other types of vulnerability actors over three disaster phases. In this Table the blue dots show 'reverse vulnerability transfers' which are defined as transfers of vulnerability made by an actor to another actor who subsequently transfers them back again. The 'o' symbol indicates that the transfers work in both directions.

Table 14: Identifiable vulnerability transfers by Murphy oil Corporation (from Table VIII in Appendices).

Transfers shown as dots	**Pre-disaster adaptation**				**Short-term post-disaster response**				**Medium-term post-disaster response**			
	Vulnerability actors				**Vulnerability actors**				**Vulnerability actors**			
Vulnerability Facet	Social	Econ	Instit	Territ	Social	Econ	Instit	Territ	Social	Econ	Instit	Territ
Social					•		•	•	•		•	•
Physical			•		•		•	•			•	•
Economic	•	•	•		•	•	□	•	•	•	•	•
Systemic		•	•			•		•	•			•
Institutional								•				•

g. Vulnerability as a managed phenomenon

The vulnerability actors may be characterized as 'vulnerability managers', always seeking to reduce their vulnerabilities and improving their resilience within a 'rational economic man' conceptualization. Most of those who experienced the Katrina disaster will have revisited their previous relaxed, over-optimistic perception of the risks of living and working in the parish, but in reality it is likely that many will adopt 'satisficer' rather than 'rational economic' positions. Even so, the conceptualization of the actors as vulnerability managers is worth pursuing.

Murphy will have acted most closely according to the rational economic model, seeking to manage the vulnerabilities of its business by reducing the refinery production disruption time to a minimum, and by repairing its plant (which suffered major damage to electrical installations) as rapidly as possible. In so doing it provided a source of additional income for many of its employees who gained from overtime payments. Murphy sought by every means possible, including legal means, to reduce the possibility of it being found negligent in the courts and having to pay financial compensation to members of the community. It moved rapidly to clean up properties, to suggest a property buy-out programme (this was partly driven by an interest in gaining land to further extend the refinery laboratories subsequently), and to reach financial settlements with as many individuals as possible without a damaging court action. It sought to minimize its businesses vulnerability to negative publicity in this way. However, these vulnerability reduction strategies failed because eventually the local community's court action proved successful. Murphy will have drawn on much of the legal and technical resources available to it in its global operation to recover as quickly and as fully as possible, with the least financial damage to its business.

Members of the local parish population differed in the degree to which they managed their vulnerabilities in a downwards direction, and they clearly used different vulnerability reduction strategies. Some sought energetically and actively to manage their vulnerabilities by for example, devoting their own labor and energies to clean up and property refurbishment where this was feasible, by playing leading roles in the local recovery committee and in the legal battle, and by actively seeking out and accessing funding sources for their recovery and their wider community's recovery. Other returnees played a much more passive role choosing to let opportunities come their way rather than seeking them, or being too depressed or otherwise in poor health to do much other than to survive from day to day. Those who chose to permanently resettle in another location very actively managed their relocation choice, and others who are still wondering about whether to return are in some cases following a very deliberate strategy of waiting until the time is right, and in other cases are locked in a sea of uncertainty about the future. We can see from this, then, that members of the local population might be categorized as vulnerability managers, something along the following lines:

- energetic, capable and active leaders of vulnerability management primarily for the community (those with good leadership and general capability skill sets, and a strong sense of community);
- energetic, capable and active vulnerability managers, principally of their own or their own family's vulnerabilities (those with good capability general skill sets);
- capable and active vulnerability managers who happen to have particularly relevant technical skill sets (e.g. local builders, repairers, plumbers, electricians, shopkeepers) who can also gain financially from putting these skills sets to good use;
- variably active and engaged vulnerability managers, with or without capabilities and skills (e.g. those who found it difficult to engage in vulnerability management either through lack of engagement, energy or knowledge and skills);

- inactive, largely non-engaged members of the community who suffer from incapacitating physical and mental illness, either chromic or caused by the effects of the disaster, and learning disabilities;
- willing but unable to be very active because of age and infirmity whose role may be more to encourage others; and
- inactive, unmotivated, non-engaged, but physically and mentally able, individuals.

Clearly, some of these categories of individuals can be termed 'vulnerability managers', but there are several categories to which this term appears inappropriate. These individuals are ones who appear to be more fatalistic, or content to drift, or know of no other way. They are likely also to be among the most vulnerable individuals in the community. In some cases their vulnerability is, or has to be, managed by others who include carers who are an additional category of vulnerability managers to those listed above.

h. The final outcome

The recovery and reconstruction phase still has a long way to go in St Bernard Parish, and this disaster phase now coincides with a new potential pre-disaster phase (see 4.0). New approaches to property construction resilience and mitigation measures are being designed into the reconstructed community to lesson future pre-disaster vulnerability. The final vulnerability outcome at this point in time (i.e. January 2010) may be summarized as follows.

For Murphy Oil Corporation and its oil refinery, the recovery and reconstruction phase is over and the dip in profits which the company experienced as a result of the direct and production losses, is also now in the past. The oil company has recovered much more rapidly than the parish community. However, Murphy remains physically and therefore economically, vulnerable to another major flood event (as well as accompanying oil contamination risks as a consequence of flooding) just as the parish still remains highly prone to tidal surge damage. This will lessen to some extent if the levee system is upgraded as is being discussed.

For members of the local parish population the recovery and reconstruction phase is on-going. As a residential and local business area, the parish remains blighted in terms of depressed property values, visible loss and residual pollution classified as high. Many are gradually reconstructing their financial security and their social networks and support groups, though some have lost relatives and neighbors in the event. All facets of vulnerability appear to be declining but there is remaining, significant residual vulnerability to a future flood disaster which is inherent in the parish's location which is keeping vulnerability at high levels (see 4.0).

6.2 Predominant "Vulnerability Actors" of territorial and eco-human systems managing territorial and ecosystems vulnerability along a disaster cycle and a series of disaster cycles – Critical forms of capital

6.2.1 The Territorial / Eco-human system of Leros, Dodecanese Islands, Greece and its water shortage problem

a. General description

Leros is a small island in the East Aegean Sea which belongs to the group of the Northern Dodecanese (map 1). Its territory amounts 53 km2 and its population 8,207 inhabitants (according to National Census 2001). During the decade 1991-2001 the island presented a slight population increase (+1.8%) in contrast with previous decades featured by population decrease. As far as employment is concerned (NSS 2001) tertiary sector comes first (66.5%), secondary sector is in the second place (13%) while the primary sector covers a very small share of the total employment (7.2%). The basic land uses in the island are: cultivated and fallowing land (~ 54%, of which agricultural land year-long cultivations cover the largest part, i.e. 70%), public and private pasture land (31.8%), forest land (4.7%) and settlements (2.03%)(National Statistical Service 1991). The island is featured by its smooth natural relief and the visible architectural and urban remnants of its Italian occupation.

The island is faced with a chronic risk, in particular the risk of water scarcity which in drought years turns to be water famine. The problem besieges no only the community of Leros but other Dodecanese islands as well and causes considerable hardship and secondary social and economic problems as well; actually it affects adversely all aspects of daily life and activity. According to the accounting by Sapountzaki and Wassenhoven (2005):

> *"The island territory is continuously and repeatedly bored for water. Altogether legal and illegal drillings are numbered more than 60 (DEYAL 2000). Several of these drilling efforts prove ineffectual or cause adverse environmental effects, since licenses whenever existent, are issued by remote administrative departments disregarding local water resource data or by Local Authorities yielding to the pressures of their electoral clientele. Underground aquifers are constantly being lowered and salinization leads gradually to deterioration of water quality. ….As a result several cultivations suffer damage due to irregular irrigation and salinized water; settlements and developments on higher ground experience, during the summer, water supply interruptions and there are acute problems of unequal distribution of water supply. ….Besides, there are risks of water contamination in the case of unauthorized wells drilled next to sewage tanks (NTUA, 2001); water pipes and electric household appliances are eroded by salinized water….there are significant water losses because of pipe leakages, due to poor maintenance….pipes burst frequently due to abrupt pressure changes when summer vacationers make their mass exodus from the island (NTUA 2001)"*

The multiplicity of the agencies and authorities responsible for water management in Leros complicates the problem. Indeed one agency, i.e. the Local Water Supply and Sewerage Company (DEYAL) is responsible for the management, operation, maintenance, technical improvement and expansion of the water and sewerage pipes; another, a Municipal Department for the determination of water rates and the construction of pumping stations; a third one, i.e. the Perfectoral Department of Land Reclamation Works (located on the distant island of Rhodes –see map 1) for private drilling licenses and finally a fourth one (the Ministry of Agriculture which has changed recently into Ministry of Rural Development and Food) for planning and constructing major infrastructure works for rain water collection (e.g. dams, artificial reservoirs etc).

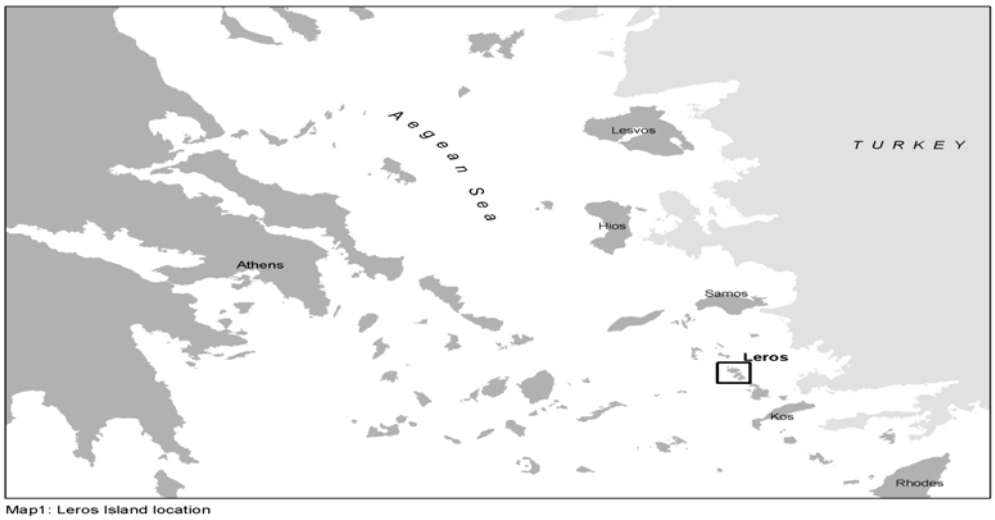


Figure 32: Map: Leros Island location

b. The predominant Vulnerability Actors in relation to the water shortage problem

Each of the above institutions, i.e. policy actors, promotes its own solution to the water shortage problem and is actually capable of steering and redistributing relevant vulnerability of other "actors", meaning not only the several consumer groups and the hydrological system but the other institutions as well. According to the analysis by Sapountzaki and Wassenhoven (2005):

> *"The central Ministry of Agriculture supports and probably exaggerates the potential contribution of dams and reservoir-lakes to the supply side of the water balance. Their insistence on this policy option is to some extent due to the pressing necessity to justify and absorb European Structural Funds destined to environmental infrastructure and also to pressures from public works contractors.*
>
> *The local Municipal Services and the Water Supply Company are very critical of oversized works which cause irreparable environmental damages…they have instead advocated water saving and the imposition of constraints on demand through stiffer pricing policies which in addition can be more profitable….Finally, the Dodecanese Prefecture a 'generous' and wasteful policy of granting numerous drill licenses".*

But the above are not the only "vulnerability actors" in the scene. The networks for illegal water procurement and "backdoor water supply play a catalytic role in distributing among the involved stakeholders the political, social, economic, environmental, physical and other impacts (and hence vulnerability) owing to the water scarcity problem. The above networks involve drillers; water carriers even local government officials and speculate on water resource shortages by creating opportunities for preferential or outright illegal satisfaction of the demand of certain consumers (tourist companies, agricultural holdings, households). Indeed these illegal networks attract clients from all consumer categories, i.e. the resident household consumers, the households of the holiday-makers, the tourism entrepreneurs and the farmers engaged in open or greenhouse cultivations (mostly citrus fruit and garden vegetables).

Above attraction is explained by the fact that the several consumer groups are dependent on water availability (each one for distinct reasons) and suffer from repercussions of water mismanagement & shortage and poor water quality. Indeed:

> *"….The resident households complain of poor water quality, water supply inequalities and water interruptions as well as proportionally high water costs…..Horticulturalists suffer from low agricultural income and reduced competitiveness, because of the adverse effects of irregular irrigation and salinized water on the roots of cucumber and tomato plants (NTUA, 2000)….Tourism entrepreneurs and vacationers are equally discontented with water supply services. In the long run water shortages affect the flow of tourists and holiday-makers and the tourism sector of the island economy as a whole."* (Sapountzaki and Wassenhoven 2005).

Besides the interests of the above groups regarding the use of the limited water resources of the island turn against one another due to systemic interrelations in the context of the wider hydrological-human system and the uncoordinated management practices. In particular, seasonal fluctuations of consumption (with high peaks in the summer months) caused by vacation homes and hotels (or rooms to let) opening in June and closing in September, restrict water availability for the resident population which is then prevented from maintaining a small vegetable garden in the summer months (Sapountzaki and Wassenhoven 2005). To refer to another example, water demand fluctuations raise excessively the costs of water infrastructure and increase the expenditure charged on the local community.

As already reported, under the circumstances several consumers belonging to various consumer categories turn to illegal practices and unauthorized suppliers for water procurement, i.e. unlicensed drills carried out by themselves, illegal deals for the procurement of water connection, water purchase from illegal drillers or water suppliers. However, these backstage arrangements in combination with the introvert, uncoordinated policies of competent institutions entail redistribution of (potential) losses and burdens (and hence vulnerability) among water users and consumers, water managers (legal and illegal) and the hydrological system.

c. The Coping Capacities of Vulnerability Actors, the resources committed and resulting Vulnerability Transferences

Table 16 below indicates the resources utilized by the several Vulnerability Actors in their attempt to cope with or benefit from the water shortage problem of Leros. Table 16 refers also to the spatial and temporal scales and levels which the Vulnerability Actors appeal to in order to get / engage these resources. It is evident from the data written on the Table that the networks of illegal water supply is the most active Actor managing to enhance its own coping capacity (and profit) by combining successfully institutional resources (such as tolerance of illegality), social resources (such as individualism in solving one's own problem), technological and natural resources (water of low level aquifers) and by appealing to close and far away sources of capital in both spatial and temporal terms.

Table 15: Identity of resources employed by the basic "Vulnerability Actors" in the island of Leros for the purpose of coping with the water shortage problem

Resources / **Actors**	**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 water of the future
Water Supply and Sewerage Company of Leros (DEYAL) – Municipality/ Municipal Council		**X** (extra financial resources coming from increased water rates imposed to consumers)		**X** (Political power to impose 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 individualistic ways of solving one's own problem; trend towards trust of 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 of public institutions and collective solutions; trust of official views)				(Traditional inherited knowledge about devices, methods and practices for water saving)

The indicated in Table 15 distribution of resources which are necessary to recovery entails transference of vulnerability from some actors to others. In detail (see Table 16):

- The central Ministry of Agriculture insisting on dams (to improve the supply side of water balance) encumbers the local community with high (functional) costs of

unnecessary infrastructure and deprives the local water management policies of essential financial resources for really effective solutions (transference of institutional vulnerability due to ineffective policies boosting lay public's mistrust and economic vulnerability).

- The local Municipality Services and Water Supply Company (DEYAL) attempt to decrease water demand (and hence alleviate the ecological system's vulnerability) by imposing stiffer pricing measures on lawful subscribers/ consumers (social/economic vulnerability); at the same time this policy mitigates DEYAL's own economic vulnerability (regarding necessary financial resources for the implementation of the appropriate water policy).

- The Dodecanese Prefecture attempts to satisfy its political clientele by granting excessive numbers of drilling licenses (benefits in institutional robustness are gained through the deterioration of the hydrological system).

- Unauthorized drillers and water suppliers speculate on the problem of water shortage by turning to advantage relevant political tolerance and institutional weaknesses (i.e. institutional capital or the lack of it); these illegal drillers and their clients (who get cheap water, satisfy their own water demand and improve their economic position) do harm to the hydrological system (ecological vulnerability), undermine institutional knowledge about water cycle data and quality and quantity of water reserves (institutional vulnerability), deteriorate public water quality consumed by lawful users and raise the share of costs sustained by them (social and economic vulnerability).

- Lawful consumers (among them hotel keepers, permanent residents, farmers) are faced with constant increase of own vulnerability (regarding water deficiency) because of vulnerability transference to them by all those private (mostly illegal) actors who manage to satisfy their water needs by depriving others and by discredited by the latter public institutions.

Due to the fact that the hydrological system accumulates vulnerability externalized by institutional, economic and social actors, exposure of these actors and the whole territorial system to the threat of water famine and poor water quality is constantly raised and hence territorial vulnerability as well. The environmental hazard is actually produced by vulnerability externalization on the part of social, economic and institutional Actors.

Table 16: Transferences of vulnerability from one actor to another

Vulnerability to / **Vulnerability from**	**Social & Economic actors: Lawful water consumers**	**Economic actor: "Black" market of water supply**	**Institutional actors**			**Eco-human-Territorial actors: The hydrological-human system of the island of Leros**
			Water Supply & Sewerage Company of Leros (DEYAL) – Municipality	**Prefecture-Department of Land Reclamation Works**	**Ministry of Agriculture**	
Social & Economic actors: Lawful water consumers			**+** Institutional (complaints about low quality services and	**0**	**0**	**-** Ecological (due to the fact that lawful consumers are compelled to

				mistrust)			water saving)
Economic actor: "Black" market of water supply		**+** Social, Physical, Economic (deterioration of public water, increased share of costs etc)	**-** Economic (illegal agencies and networks profit from the water problem)	**+** Institutional (cancellation of capability to exert informed water policies)	**+** Institutional (complicating the task of issuance of drilling licenses)	**0**	**+** Ecological (damage to the hydrological system due to uncontrolled drillings)
INSTITUTIONAL ACTORS	**Water Supply & Sewerage Company of Leros (DEYAL) – Municipality**	**+** Economic (due to increases in water prices)	**0**	**-** Economic (due to improvement of the finances of the company)	**0**	**0**	**-** Ecological (relief of the ecosystem as a result of water saving)
	Prefecture-Department of Land Reclamation Works	**-** Social & Economic (selective satisfaction of the needs of certain consumers)	**0**	**+** Institutional (deterioration of quality of public water and making harder the task of DEYAL)	**-** Institutional (satisfaction of the needs of political clienteles)	**0**	**+** Ecological (deterioration of the hydrological system)
	Ministry of Agriculture	**+** Economic (waste of money and other resources)	**0**	**+** Institutional (ineffective policies boosting lay public's mistrust)	**0**	**-** Institutional (fulfillment of political respon/ties)	**+** Ecological (damage to the environment due to large scale technical infrastructure)
Eco-human-Territorial actors: The hydrological-human system of the island of Leros		**-** Social & Economic (due to domination of illegal activities profiting from water shortage)	**-** Social & Economic (due to political acceptance of the illegal agencies)	**+** Institutional (competent institutions are involved with a complicated problem & blamed for mis-management)	**+** Institutional (competent institutions are blamed for mis-management)	**+** Institutional (competent institutions are blamed for mis-management)	

O No change, **-** Reduction, **+** Increase

The environmental hazard/risk of water famine or hydrological drought is a chronic risk with peaks (crises) and periods of risk abatement succeeding one another. In this case the model of the four standard stages (prevention→disaster manifestation→emergency/relief→recovery) which can be applied in the case of extreme risks to depict with comparative accuracy the disaster management cycle is not valid in the case of chronic risks. The hazard itself and exposure to it of the involved actors/systems

depends to a large extent on vulnerability regulation and management on the part of the Actors themselves. Table 17 illustrates anticipations of vulnerability trajectories and end-vulnerability of the basic "water-management actors" in Leros by taking into account transferences occurring under two different scenarios:

1st Scenario: DEYAL (the local water supply company) and the Municipality gain the upper hand in water management and impose a strict policy for water saving based on always stiffer water prices. At the same time they proclaim war against the "black market" of water.

2nd Scenario: The illegal networks of water supply expand their influence and become the predominant water supplier in the island; due to their status their activity as regards water abstraction and exploitation is not restricted by any kind of environmental / water law or institutional control.

Tables 16 and 17 indicate clearly that:

- It is not only institutional actors that transfer vulnerability to social, economic and ultimately territorial actors; the reverse is also valid, i.e. the latter can transfer vulnerability to the first and this is mostly institutional vulnerability.
- Ecological vulnerability is the most easily generated and transferred /transformed form of vulnerability because eco-systems are pathetic recipients of damages and impacts originating from human actors. Eco-systems are only insufficient "vulnerability managers" or actors.
- Alleviation or avoidance of social, economic and institutional vulnerability in the short term may be gained by deteriorating long term vulnerability of ecosystems; however the reverse is not possible, i.e. long term decrease of social, economic or institutional vulnerability cannot be traded off with short term ecological vulnerability.

The example of Leros hydrological drought proves that the levels of each vulnerability facet of a territorial or eco-human system and its sub-systems and relevant vulnerability distributions in time and space are clearly a matter of allocation of power among the several "vulnerability actors". This power in turn is a matter of accessibility to forms of capital that are crucial in response / coping capacity.

Table 17: Actors' additional vulnerability coming from other actors and accumulated in the course of time in the case of hydrological drought of Leros – Two different scenarios

Basic Actors accumulating / mitigating their vulnerability / **Vulnerability management scenarios**	**SOCIO ECONOMIC ACTORS: Lawful water consumers**	**ECONOMIC ACTORS: Networks of illegal water procurement**	**INSTITUTIONAL ACTORS**			**ECOHUMAN-TERRITORIAL ACTORS: The hydrological-human system of the island of Leros**
			Water Supply & Sewerage Company of Leros (DEYAL) – Municipality	**Prefecture-Department of Land Reclamation Works**	**Ministry of Agriculture**	
SCENARIO 1: DEYAL gains the upper hand in water management and the	**-** (Physical) • Improvement of public water quality **+ -** (Social &	**+ +** (Economic) • Illegal networks lose their accessibility to resources and	**+ -** (Institutional) • DEYAL is blamed for stiff water rate policies • DEYAL is acknowledge	**+ -** (Institutional) • Prefecture is suspected for clientelistic attitude of granting excessive	**0**	**- - - -** (Ecological-long term) • Relief of the ecosystem as a result of water saving – Enrichment of

channels of illegal water supply are controlled and restricted	Economic) • Social & economic improvements due to improved water quality and availability • Growing credibility of DEYAL's policy • Increased water prices	economic profits **+ +** (Social) • Illegal networks are blamed for water famine situation	d as an effective water manager **- -** (Economic)	drilling licenses • Pressures for more & more licenses are relieved		aquifers **- -** (Territorial-long term) • Improvement of water availability • Curing of socio-economic problems owing to water shortage
SCENARIO 2: Illegal networks of water procurement are consolidated and wangle expansion of their activity and clientele	**+ +** (Physical) • Deterioration of public water and risks to health **+ +** (Social & Economic) • Socio-economic impacts due to deterioration of public water • Continuously increasing water prices • Trust to DEYAL's policy shaked	**- -** (Economic short-term) • Always increasing illegitimate profits out of the exploitation of the water problem • Satisfaction of the needs of selective consumer groups	**+** (Economic) • Deterioration of DEYAL's finances **+ + + +** (Institutional) • Cancellation of DEYAL's capability to plan/ exert informed water policies • Low quality water supply services & mistrust of consumers • Shrinkage of water sources accessible to DEYAL	**+ -** (Institutional-short term)	**- -** (Institutional-short term) • Faith and hope is put on dams and reservoir-lakes due to the deplete of aquifers • Accommodation of central ministry's political responsibilities and interrelated economic interests	**+ + + +** (Ecological long-term) • Due to over-exploitation of water resources the hydrological system is altered • Water contamination due to excessive and inappropriate drilling locations **+ +** (Territorial long-term) • Deterioration of the water shortage problem and dependence of the island community on external resources

6.2.2 The Territorial/Eco-human system of Northern Negev (Israel) and its drought problem

a. Drought as climatic event

Droughts are considered an extreme climatic event and regarded as the most serious climatic risk in the 20th century (Obasi, 1994; Vicente-Serrano et al., 2004). Having natural environmental and socio-economic dimensions, it is estimated that droughts may affect up to hundreds of millions of people each year (Bruins, 2000). In addition to direct impact during the drought years, all researchers concur that droughts may entail severe global and long-term consequences that may impact almost all climate zones.

The high occurrence of recent droughts and their harsh consequences were reported by many countries in North and South America (Schlesinger et al., 1990, Wilhite et al., 2000; Biswas, 2001; Ortega-Ochoa, 2008), Africa (Nicholson et al., 1998; Wilhite, 2000), and Europe (Rebetez et al., 2006). Usually, the impact of droughts is strongly related to the percentage of the drylands in the country. This relation is observed in the southern Mediterranean (Swearingen, 1992; Le Houerou, 1996; Puigdefábregas and Mendizabal,

1998), or at the northern Mediterranean such as Greece (Katsoulis and Tsangaris, 1994; Dalezios et al., 2000; Livada and Assimakopoulos, 2007; Tsakiris et al., 2007), Italy (Brunetti et al., 2000, 2004; Piccarreta et al., 2004), Spain (Piñol et al., 1998; Puigdefábregas and Mendizabal, 1998; Peñuelas et al., 2001; Roberts, 2002; Vicento-Serrano et al., 2004; Fornés et al., 2005; Iglesias et al., 2007) and France (Debaeke et al., 1998;Ciais et al., 2005).

This report studies vulnerability to droughts with application to the Northern Negev drylands.

b. Droughts in Northern Negev

Drought may be defined by season or year. Short growing season in the Northern Negev, makes it possible to refer to drought years. We define "drought year" as a year during which the interrelations between rain-evaporation-soil results in a substantial decrease in the production of the natural vegetation and crops below the average yield. The comparison is based on the yield of those crops that during most of the years grow successfully in this region, guaranteeing descent revenue to the farmers.

While drought may be defined as a year during which its precipitation falls short of average (WMO, 1975 in Le Houerou, 1996), one should bear in mind that rain precipitation per se is insufficient for forecasting the plant production. The latter is mainly controlled by the soil moisture which reflects the amount and intensity of the rain: evaporation and soil properties. While high intensity rains may be lost as a result of high runoff (Kidron and Yair, 1997), the evaporation rate is a function of temperature and wind (Davenport, 1967; Blackie and Simpson, 1993). As for the soil properties, both the amount and types of clay and the amount of organic matter may markedly affect the soil moisture content (Cantón et al., 2004). The soil moisture, which is linked to the depth of the wetting front (the higher the moisture the deeper the wetting front) may thus be seen as an integration of almost all factors that determine future plant yield. Yet, one parameter missing is timing. Sufficient moisture should be present at certain crucial times, thus during the early stages of plant establishment and during seed maturing. In the Northern Negev, a minimum precipitation of 100 mm until the middle of December is necessary for guaranteeing early development of the wheat. Sufficient moisture is needed during seed maturation in March. Roughly, each 100 mm of rain wets the ground to about 50 cm. It means that in the Bet Kama area of the Northern Negev, where we perform our field study, and where average precipitation is 230 mm, moisture reaches ~110 cm during an average year with a depth of ~50 cm until the middle of December.

For the Bet Kana area it implies that while precipitation during an average year may fluctuate between 180-280 mm and precipitation >280 mm will be considered as a wet year, annual precipitation of 140-180 mm would imply slight drought and <140 mm a severe drought. Yet, regardless of the annual precipitation, a year with precipitation of <100 mm until the middle of December will also imply a drought year. Generally speaking, we will consider a year as "an average" if the precipitation in this year remains within the ±25% interval around the average. In a year of severe drought, precipitation should be at least 40% below average.

c. Droughts and agriculture production

A decrease in crop yield may be a result of different factors, which are not related to precipitation and droughts, e.g., hails, frosts or diseases. However, we limit the current discussion to droughts only. Furthermore, a sharp decrease in crop yield may be a result of the wrong farmer's decisions. Wrong choice regarding the crop or of the cultivation practice, e.g., decision to grow wheat rather than barely that is more resistance to drought, or improper choice of the time of sowing may markedly affect the crop yield. These options will be excluded from our summary and from the definition of drought. As long as the farmer

makes decisions within the common practice characteristic of the region, a decrease in the crop yield as a result of a shortage or improper timing of the precipitation will be dealt herein as resulting from drought.

Despite large-scale occurrence, and the severe agricultural consequences, the scope of the research of spatial and temporal vulnerability of drylands to droughts is limited and our understanding of the vulnerability of the drylands to droughts is only partial. Neither the terminology nor the definitions are always clear and unambiguous. This report studies vulnerability to droughts with application to the Northern Negev drylands.

d. The meaning of Vulnerability to Drought

The landscape system remains within the limits of robustness until its components and function vary quantitatively. Drought can push the system beyond these limits and influence the landscape qualitatively and, as a consequence, the entire landscape may collapse. That is why we define the vulnerability to drought as follows:

The landscape is vulnerable to drought if its structure and qualitative functioning cannot be preserved during the period of droughts.

To specify, let us characterize the landscape system S by the set of state variables $\sigma = (\sigma_1, \sigma_2, \sigma_3, \ldots)$ and ignore, for simplicity, hierarchical structure of S and spatial variability in S characteristics; that is, we consider S as "averaged" over space (Benenson and Torrens, 2004). In case of the Negev landscape, the variables are the average soil moisture, fractions of the area that is used for intensive/extensive cultivation of crops, fraction of the area that can be used for intensive/extensive husbandry, the urban and agriculture population density and the density of the farms and farmers of different kinds, etc. The values of the state variables change in time, and, thus, to characterize temporal variability of the system S (we consider spatial variability in the following sections), we have to characterize the state of the system S in time, and consider σ as $\tilde{\sigma}_t = (\sigma_{1t}, \sigma_{2t}, \sigma_{3t}, \ldots)$

In what follows we limit ourselves to the society-based view of S. To fit societal needs, the validity of each σ_{it} (say, preserving "some" Negev population or "some" agriculture) is insufficient. The society need demand to preserve each σ_{it} within certain limits, $(\sigma_{imin}, \sigma_{imax})$ - "limits of robustness", which are established by the society itself and are interpreted as sufficient for preserving or even development of the system according the society's view of the system's future.

In these terms, the system S is robust if it functions in a way that despite varying environmental conditions (say, precipitation level in case of the Northern Negev) all state variables σ_{it} remain sufficiently far from the boundary values σ_{imin} and σ_{imax}. The system S is vulnerable if the system's state vector σ_t approaches the boundaries of robustness σ_{min} or σ_{max}.

In terms of landscapes vulnerability to droughts, robust system Sr possesses sufficient "coping capacity" that enables to preserve its structure, main parameters and the way of functioning during drought. Robust system Sr fully restores itself afterwards. The coping capacity of the vulnerable system Sv is low. Vulnerable system Sv qualitatively and irreversibly changes in respond to the drought.

Schematically, this definition is illustrated by Figure 33:

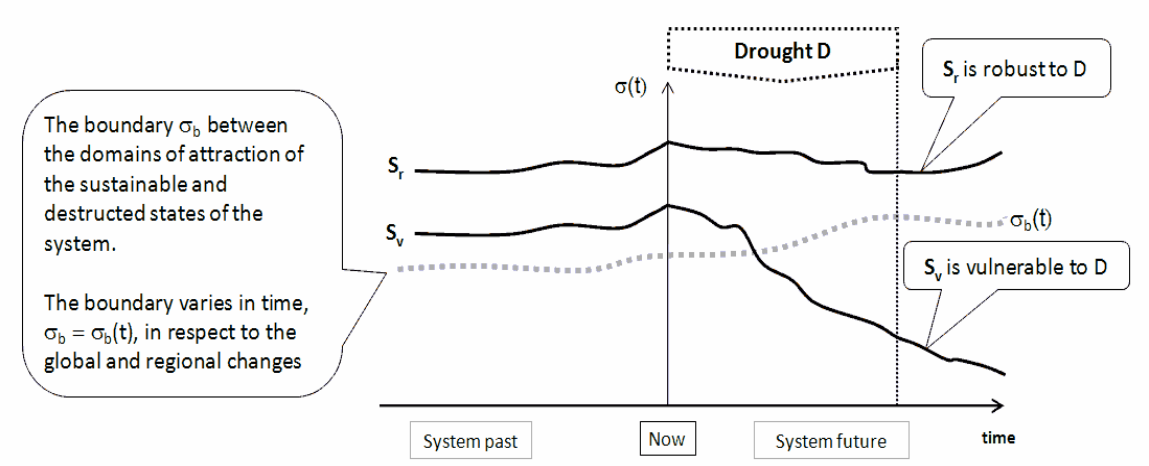


Figure 33: Robust system S_r possesses sufficient coping capacity that enables to preserve its structure, main parameters and the way of functioning during drought. Robust system S_r fully restores itself afterwards. The coping capacity of the vulnerable system S_v is low. Vulnerable system S_v qualitatively and irreversibly changes in respond to the drought. For simplicity, only the lower limit of robustness σ_{min}, denoted in the figure as σ_b, is presented.

e. Population and land use in the Northern Negev

Israel stands in the forefront of the everlasting battle against droughts. This is especially the case in the Northern Negev (100-450 mm of annual precipitation) in the southern part of the country. Excluding the urban population (~250,000 in the Jewish sector and 50% of the total of ~180,000 Bedouins), the rural population in the Negev can be divided into two main sectors, that of the Jewish farmers which inhabit settlements called Kibbutzim and Moshavim (with ~60,000 inhabitant) and that of the Bedouin (Muslim) settlements (with ~90,000 inhabitants) (Figure 34).

While agriculture is an important income in the Kibutzim and Moshavim (Fig. 35), agriculture and livestock grazing is an important occupation in the Bedouin sector (Fig. 35), with cerca 1300 Bedouin sheep owners.

a

b

Figure 34: Jewish rural settlement of a Moshav (a) and rural settlement of Bedouins (b) in the Northern Negev.

a

b

Figure 35: Jewish (a) and Bedouin (b) agriculture at the Northern Negev

Our analysis will focus on the Negev rural areas, which dynamics is determined by (a) the behavior of the Jewish farmers, which comprise the majority of the farmers (b) the Bedouin sheep owners, which comprises the majority of the sheep owners and (c) the interrelations between them.

Urban population

The Negev urban population (~250,000 Jews and ~90,000 Bedouins) is not vulnerable to drought. The prices of the agricultural production in the Negev cities are determined by the supply and demand of the entire consumer market in the country. Although a country-wide

drought may affect indeed the market prices, one may conclude that the urban population in the Northern Negev is not affected by regional droughts. However as will be described in section 5.3, the growth rate of the Bedouin population is affected indirectly as a result of absence of agricultural resources which contributes to the migration of agricultural population from temporary settlements to towns.

Jewish agriculture population

Both Kibbutzim and Moshavim differ in their degree of property and decision sharing. Kibbutzim are characterized by relatively high and Moshavim by low degree of sharing. While in Moshavim the means of production are shared, e.g., one dairy serving all cow sheds, Kibbutzim were founded upon staunch socialist ideology, equal pay for all members, common dining hall, etc. (Leviatan et al., 1998) and the share of the property, labor and activities still remains high. Yet, extensive privatization has taken place in the Kibbutzim in the last 15 years, with each Kibbutz community deciding separately to what extent it will privatize the property and the labor and which form privatization will take (Leviatan et al., 1998). At present, agriculture and other lands usually remains in possession of the entire Kibbutz community. Currently, professionals, mostly from the Kibbutz manage the agricultural production. In some cases professionals are hired from outside the Kibbutz.

Moshavim members own their own fields and, usually, the size of the members' fields are similar. A small portion of the member's lands, ca 2 ha, is located near the member's house, and are usually exploited by the Moshav members for expressing individual taste by growing crops or flowers, usually in greenhouses. The larger part of the lands, ca 20 ha is located beyond the residential area. These lands are usually cultivated jointly by a professional company, which shares its profits with the members of the Moshav.

Bedouin sheep owners

Approximately 1300 Bedouin sheep owners are in the Negev having on average 200 sheep per mob. The traditional way of raising livestock involves outdoor grazing for 6-10 months of the year, between December and October (Fig. 36), and feeding the herd "indoors" during the rest of the year, in barns or paddocks, with hay, grains and grasses.

a

b

Figure 36: Grazing on local Bedouin fields near the Bedouin town of Rahat (a) and on agricultural fields (b).

During the last decade the part of intensive husbandry is increasing with outdoor grazing being reduced to <6 months. According to the chief guide of the Ministry of Agriculture for the Bedouin sector, 10% of the Bedouin herd owners have completely switched to intensive husbandry.

The adoption of new local sheep breeds, which now comprise already 30-40% of the total livestock, and the use of hormones and insemination techniques, substantially increase the fertility of the ewes. While 40 years ago only ca 35% of the ewes conceived, the rate now reached 120% (above 100% due to twins).

A constant increase in the irrigated fields is taking place in the Northern Negev. This is primarily the result of diverting purified sewage water from Tel Aviv area to the Negev. Apart from this source (called Safdan) other sources of water were developed. It include purification of local sewage water, desalination of brackish water and harvesting of runoff water, all resulting in a substantial increase in the amount of water available for irrigation. As a result, the amount of the lands available for sheep pasture decreased by ~30% during the last 20 years. The amount of sheep on the other hand increased during this period of time. Albeit reduction of the open pastures area, sheep husbandry adopted this change. Sheep husbandry in barns is becoming more popular – it reduces the required manpower, decreases ewe mortality from diseases and in creases fertility. Sheep rearing, which develops towards intensive husbandry, has positive impact upon the Negev environment. With the restriction of free grazing, more organic matter is left in the soil and soil fertility increases. With the reduction in surface trampling wind and water erosion is also markedly decreased (Zhao et al., 2005).

f. The landscape structure and functioning of Northern Negev

The landscape in general and the Northern Negev landscape in particular are considered below from the Geosimulation point of view (Benenson and Torrens, 2004). Namely, the landscape is considered to comprise of (a) passive natural and artificial objects, e.g., agriculture fields, roads, water pipes, and (b) active local agents usually representing humans and human institutions. Objects and agents are characterized by state – the set of variables, which include location of an object or agent.

Objects change their state following the changes in environmental conditions and under the influence of agents.

Agents behave (i.e., make decisions and implement them) and interact and by that influence and change their states and the state of other agents and objects.

In the Negev we distinguish several types of objects and agents.

g. Negev's landscape objects and agents

For the purposes of vulnerability studies, the Northern Negev landscape can be represented by the objects and agents of several types, belonging to different levels of landscape hierarchy (Figure 37):

Objects:

1. Cities with Beer Sheba being the leading

2. Jewish towns

3. Bedouins towns

4. Jewish agriculture settlements: Moshavim and Kibbutzim

5. Bedouin agriculture settlements

6. Agriculture fields

7. Non-agriculture land-lots, which are often subjected to tree planting and therefore can be called forests (Fig. 2a)

8. Infrastructure objects: rivers, roads, pipelines of water, electricity and sewage

Agents:

1. Jewish farmers – local agents

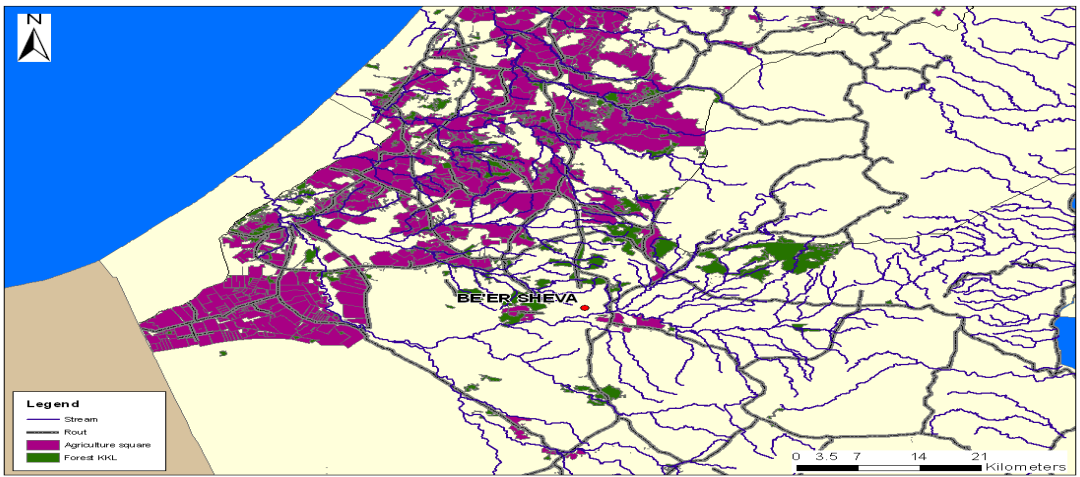
2. Bedouin farmers – local agents

3. Mekorot (state owned company responsible for the water supply for agriculture), "Ministry of Agriculture" and "Ministry of Finance", responsible for demarcating the areas prone to droughts, where farmers receive compensation during the drought years – institutional agents

Taken together these objects and agents construct complex Negev landscape

Local agents

Farmers cultivating crops and sheep owners are local agents, influencing the landscape in the vicinity of their location. For the current summary we refer only to the Jewish farmers and to Bedouin (Arab) sheep owners that are by far the majority of the crop cultivators and sheep owners in the Northern Negev, respectively.



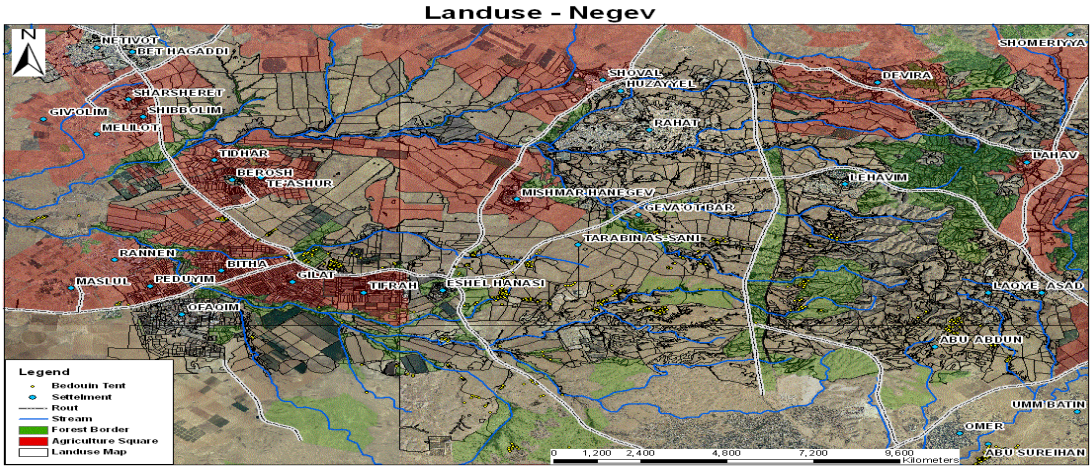


Figure 37: Agricultural fields and non-agriculture lots (forest)(a) and a complex land-use map of the Northern Negev (b).

Institutional agents

Several *institutional* agents that act within the Negev landscape also influence the entire landscape system. The institutional agent "Mekorot" (the governmental company responsible for water supply in the Negev) decides upon the quota of water given to each area or farmer. The "Ministry of Agriculture" and "Ministry of Finance" agents are responsible for demarcating the areas prone to droughts, where farmers receive compensation (i.e., full coverage of expenses) during the drought years.

The institutional agents are responsible for managing the entire Negev landscape system and keeping its parameters, both averaged over the entire landscape, and at the level of the spatial units of lower hierarchical levels, sufficiently far from the boundaries of robustness, as presented in Figure 33.

In practice, institutional agents make decisions at certain moments of time and thus, the landscape system can cross the boundaries of robustness and collapse due to delays in making decisions or in their implementation. Institutional agent aims at minimizing the risk of collapse over the entire area. Consequently, they disperse their actions over space. This also regards innovative ideas, as introduction of a new crop: in order not to drastically "shake the boat", innovative ideas will be gradually examined, whether by checking them out first in certain areas with different micro-climatic and soil conditions (space controlled), or by dispersing it over time (years, i.e. time controlled).

Landscape dynamics as an outcome of agents' behavior and interactions

The human view of the landscape system focuses on its efficiency – the ability to facilitate the persistent well-being of the currently existing modern settlements in this region. The efficient system is, thus, necessarily robust. In case of the Northern Negev, this view is institutionalized by the Israeli government, which aims at inhabiting the Negev as a part of the general policy to disperse the country's population from the center to the periphery.

Institutional agents play a major role in making the landscape system efficient. However, the consequences of their decisions are often uncertain, due to the lack of knowledge on the system's responses, both in space and time. The spatial response is uncertain because of lack of knowledge about the variety of the local conditions and the reaction of agents' and objects' to the changes there. The temporal response is uncertain because of the lack of

knowledge of the landscape unit's reaction to the changes in time. The active behavior of the local agents can be additional reason of inefficiency of the institutional agents' decisions; local agents can react inadequately following their short-term goals which are not necessarily compatible with the landscape efficiency.

h. Spatial variation in local vulnerability to droughts

Basically, the general concept of vulnerability, as expressed in section d and Figure 33, can be applied to every object or set of objects at any hierarchical level of the system's organization. If we consider, for example, the agriculture lands of a Kibbutz or of a Bedouin family, the landscape structure over this area can be more vulnerable or less vulnerable to the droughts depending on the level of land exploitation, soil content, population that depends on the productivity of the area's landscape system, agriculture practice, etc. Different agents, e.g. different agriculture settlements or Bedouin families can manage their lands in different ways and, thus, the landscape vulnerability can vary in space even in case of the uniform environmental conditions and population distribution.

As a result, the local vulnerability, characteristic of the objects or group of objects of interest vary not only in time, but also in space and the concept of robustness and vulnerability, as presented in section c can be applied to them. Some areas can be vulnerable while the other can be robust to the draught of the same intensity and duration (Figure 38):

The ways of the agents' influence on local vulnerability are numerous. The decision to sow a more drought-resistant crop such as barely instead of the more drought-sensitive wheat may determine future vulnerability as well as more general decision on rotation of crops within a field. Despite the general necessity of rotation that aims at reducing the risk of exhausting the fields and the development of diseases, rain-fed wheat may be affected during a next drought year.

Spatial variation in area's vulnerability can result from differences in the plant demand to water or slight differences in the moisture content of the soil. While barely may be resilient at certain fields due to shallower roots and shorter growing period, wheat that requires more water, may be markedly affected by the drought. Variable response may also result from differences in the clay content of the soils and slight differences in the soil moisture content, such as a result of aspect, spatial variability in rain intensity that may lead to higher runoff (and therefore lower availability of water) in certain fields or as a result of the cultivation practice employed.

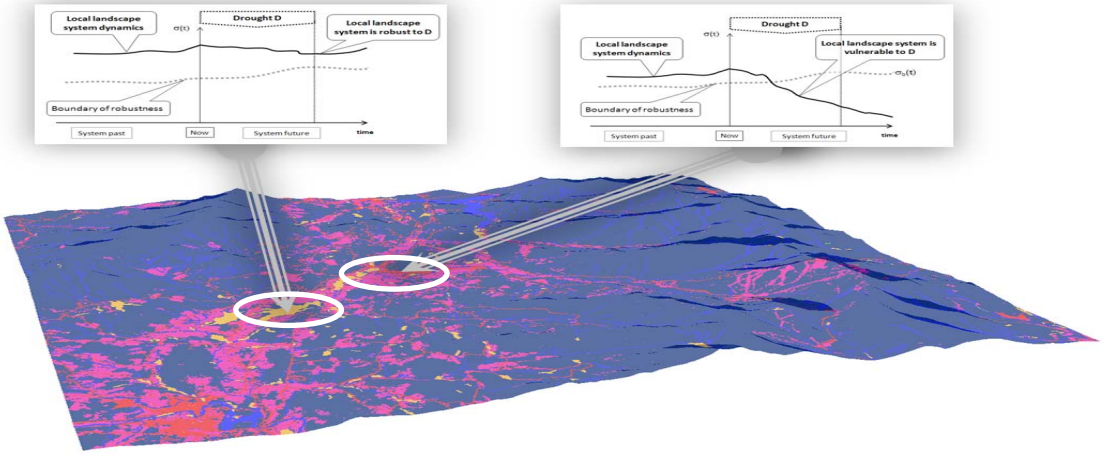


Figure 38: Spatial variability of the vulnerability to droughts: Given the intensity and duration of the drought D, the area A is robust to D, while the area B is vulnerable to D.

The use of the no-tillage cultivation technique and the use of means to increase the water storage in the soil (such as by creating depressions), results in an increase in the moisture content of the soil (Bonfil, 1999). Similarly, the addition of organic matter which serves to increase the moisture content of the soil (Cantón et al., 2004) may contribute to the "success" of certain fields. Higher moisture content may also characterize "sun-shaded" aspects such as the northern aspect in the Negev.

Spatial variability of the vulnerability may also stem from the time of sowing or the timing of rain within a certain area. Late precipitation may result in area's wrong functioning although the total amount of precipitation remains at the average level. Likewise, a decision to sow early or late may determine the 'success" of the crop within a certain year, depending of the precipitation regime.

i. Spatial interactions between objects and agents and vulnerability to droughts

Agents' decisions regarding one or several objects influence other objects and agents. The simplest example is the decision of the institutional agents, limited in its resources, to favor one area on the expense of the others, e.g., the decision to allocate irrigation pipelines to one area or to include or exclude an area from those areas in which the farmers are guaranteed a certain compensation during drought known as the "drought line' (see below).

As all landscape is subjected to institutional agents, the interactions between them and the other objects and agents usually influence the spatial distribution of vulnerability to drought, strengthening the robustness of some parts of the landscapes and weakening the others. However, the interactions between the local agents - farmers and sheep owners - are not less important. The most important example in the Negev is the relation between area's vulnerability to droughts and interactions between farmers and sheep owners. The farmers may decide whether to allow grazing and while the sheep owners may decide whether to purchase the right to graze on agricultural fields or rather to purchase hay to feed the sheep at the barn or paddock in their own property. While the decision of the farmers to restrict the agricultural fields available for grazing may theoretically reduce the herds in the Northern Negev, they may on the other hand enforce new husbandry techniques, namely, sheep rearing in barns. On the other hand, also a decision of the sheep owners not purchase the right to graze on the fields may result in future consequences. While reducing the revenue received from the fields, it may on the other hand encourage farmers to take advantage of the straw left in the field by using it as mulch. This point will be further expanded towards the end of this report.

j. Temporal vulnerability to drought

The history of a certain field or group of fields strongly determines their vulnerability to drought. The amount of precipitation during the previous year may affect the moisture content of fields during the current year and may determine the success or failure of the crop. Likewise, the growth of wheat on fields that were irrigated during the previous year may determine the "success" of the yield of the wheat: extra moisture preserved within these soils may provide the necessary water for a relatively "successful" crop. Likewise, addition of organic matter during the previous year may determine the yield during the current year. Similarly, sowing of a summer crop such as watermelon may result in a severe depletion of the moisture content of the soil during the following year, which may result in turn in a substantial drop in the wheat yield during the following winter. By the increase in

the amount of water, crop production at fields that were irrigated during the previous year may double itself. It implies more grains, hay and straw.

k. Evolution of Negev's landscapes towards robustness to droughts

Frequent droughts in the Negev pose a severe challenge to the landscape robustness and effectiveness. The institutional agents react to the droughts by establishing land-management and water supply policies which increase area's resilience to droughts and consistently decrease Negev's vulnerability.

Agriculture land-use policy: making the landscape robust to droughts

Starting from 1950s various action were undertaken by the Israeli government (through institutional agents) to alleviate the impact of drought:

a. Guaranteeing sufficient water supply for the inhabitants and some of the agricultural fields of the Northern Negev. Farmers can only use water in accordance with the quota of water that they receive from the National Water Company (entitled Mekorot).
b. Demarcating a drought zone, the "drought line" prone to droughts, in which farmers will be guaranteed the return of their expenses in the case of droughts. The expenses are calculated as the difference between the amount of money received as revenue (such as straw in a very severe drought) and their total expenses for cultivating the rain-fed fields during the drought year. While all farmers having fields within the "Line Zone" are entitled to compensation that cover their expenses, these fields do not yield any income and frequent years without income may have severe economical consequences upon the farmers.
c. Establishing infrastructure for research and free guidance for the local farmers and sheep owners.
d. Directing purified waste water from the populated northern cities of Israel to the agricultural fields in the Negev.
e. Exploring additional sources of water such as runoff harvesting, waste water purification plants and desalination of fossil brackish water for agricultural use (Tal, 2006).
f. Exploring new irrigation and cultivation techniques aiming to increase production while decreasing its cost, such as no-tillage cultivation method and the adoption of new varieties of wheat that are relatively resilience to drought.
g. Developing new varieties of wheat and sheep. These varieties, developed in the Vulcanic Research Center of the Ministry of Agriculture, are much better adapted to the local desert conditions.

The dynamics of agriculture land-use distribution

Local agents adopt policy as established by the institutional agents in various ways. Some of them do it successfully thus decreasing vulnerability of the areas they are responsible of, while the others fail to relate between their local need and behaviors and limitations of the regional policy.

Frequent droughts enforce local agents, both Jewish farmers and Bedouin sheep owners, to increase their resilience. Yet, by far, the Jewish farmers are the first reacting to the droughts. In order to preserve their revenue on the expense of the rain-fed fields that do not produce any income during drought years, they turn more fields into irrigated fields and increase the wheat crop on fields. Jewish farmers also change the proportion of the crops.

The area of irrigated wheat plots grows on the expense of rain-fed wheat areas. This process results in decrease of the areas that may be available for grazing in the drought years. Bedouin sheep owners have to respond to these developments. One option can be restricting the number of sheep. However, the demand for the products of Bedouin farming remains steadily high and this makes the restriction option highly unlikely, as indeed is the case. Consequently, sheep owners follow the line of intensive development and adopt new techniques of sheep rearing, namely in barns and paddocks.

While taking place, the change of the Bedouin husbandry from extensive to intensive takes place with delay. To date, ca 10% of the sheep is grown in barns and paddocks with no outdoor grazing, which is yet below the capacity of the area for intensive husbandry

Frequent droughts bring about another mechanism of sustainability, namely the adoption of non-conventional cultivation of wheat using no-tillage technique. By sowing the wheat without plugging and turning over the soil, higher amount of organic matter is preserved in the soil. As a result, the water storage and hence the soil moisture also increase. On average no-tillage techniques increase the wheat yield by ~10%. As a result, due to the adoption of the no-tillage technique and due to the increase in wheat yields in fields that were subjected to irrigation during the previous year, the amount of available hay and straw that serve for feeding sheep is also increasing, making it more plausible for the Bedouins to switch to intensive husbandry

The sedentary sheep rearing further affects Jewish farmers. Indeed, with a decrease in the revenue received by the farmers from the sheep owners, the extra straw left in the field further encourages farmers to adopt no-tillage technique for wheat cultivation. By serving as mulch, the intact straw may further increase the moisture content of the soil, facilitating a higher yield during the following year. And thus, the combination of no-tillage plus the use of the straw as mulch by the farmer may further substantially increase the field's soil moisture and hence the wheat yield.

As a result, the restriction of the available fields for grazing does result in an increase in the vulnerability of this sector in the Negev. Conversely, it forces the sheep owners to adopt sedentary husbandry techniques, which, in addition increase the revenue of the herd owner and serve the environment by restricting trampling and reducing the risk of soil erosion by wind and water.

With concomitant developments within the Bedouin society which results in a shortage of manpower for grazing, more and more sheep owners are switching into intensive husbandry, which result in higher economical revenue. This feedback governs the systems' dynamics reducing grazing on the one hand and extending adoption of the no-tillage cultivation technique on the other.

The adaptation to droughts entails qualitative changes in the population distribution in the Negev. While the changes in crop cultivating do not influence much the population of Moshavim and Kibbitzim, the changes in husbandry practice enforces critical changes in Bedouin life style and spatial distribution. The urbanization of the Bedouin population has two reasons and the major is dramatic demographic change of the Bedouin population. The extensive agriculture is the secondary, but still very important reason of urbanization among the Bedouin population which is forced to migrate into the urban settlements following essential reduction of the amount and quality of the open land for grazing. Indeed, during last 20 years, the proportion of the urban Bedouin population grew from around 20% to 50% while the amount of grazing lands decreased by ~30%. The droughts thus enforce the Bedouin transition from semi-nomadic or tent settlements to semi-urban and urban settlements. From the landscape point of view, these changes cause an impressive increase in the number and population of the Bedouin towns.

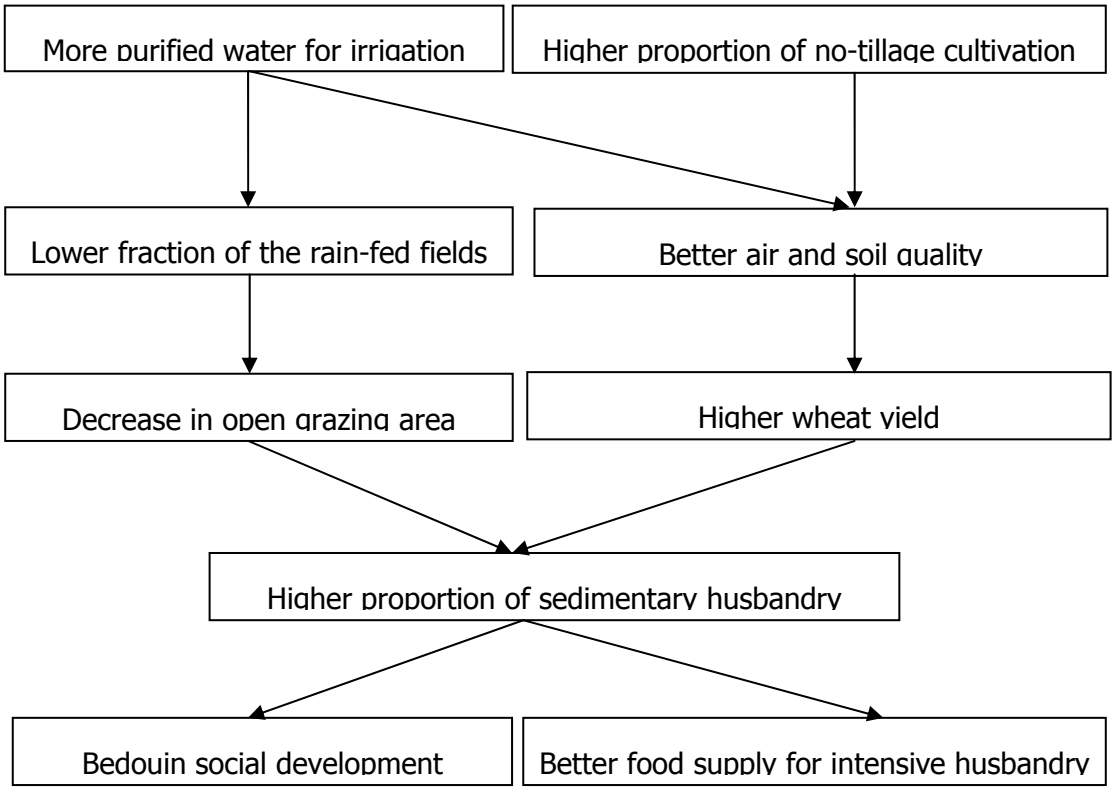


Figure 39: General loop of local agents' co-adaptation to the agriculture policy in Negev by extending the areas of intensive on expense of the extensive agriculture.

In summary, co-adaptation by intensification of the crop and husbandry agriculture is a win-win behavior and has several advantages, all decreasing landscape vulnerability. These are: (a) Introduction of high quality fruits and vegetables using brackish water (having a salinity of 3-4 times of regular portable water) (Nativ, 2004); (b) the increase in grains, hay and straw yield following new cultivation techniques, which benefit both farmers and sheep owners (c) The lack of a need to allocate family members to wonder with the sheep, thus increasing their opportunities for education (d) the increase in the revenue of the sheep owners once adopting sedentary husbandry (e) the contribution to the environment by using more water-saving techniques, increasing the organic matter in open fields, and reducing trampling which in turn reduce water and wind erosion.

The proposed scheme of the Negev's landscape vulnerability is implemented in the agent-based simulation model of the Northern Negev landscape dynamics, which is developed in the TAU team and is applying now for investigating Negev's spatio-temporal vulnerability to droughts. The model is based on the explicit representation of Negev's objects and agents (see section 3.2) and the results of the model study will be part of the ENSURE WP4 and WP5 reports.

6.2.3 Mechanisms of Vulnerability Transference in the Abruzzo earthquake case

The Abruzzo case has been presented in Del. 2.1 in order to explain the severe state of damages, compared with the "moderate" intensity of the event (M=5,8 Richter scale), caused by the earthquake occurred on the 6th of April 2009. Important points of weaknesses had been identified within the institutional field and, in detail in some mechanisms likely responsible for having induced or exacerbated vulnerabilities of both the social and physical system.

The considerations made in the immediate aftermath of the earthquake can be critically examined after 10 months on the base of new elements captured from the investigations carried out up to now, for better understanding what happened in the night of the main earthquake in terms of failure of mechanisms to cope with the event and, in such a way, for highlighting vulnerability factors. Hence, this contribution is devoted to represent first of all an update in respect to what has been presented in Del. 2.1 in terms of "supposed" sources of vulnerability and to provide other elements of analysis for examining possible mechanisms for the transfer of vulnerability from some groups of actors to others and shifting from one stage of the disaster cycle to the next one. Finally, by taking into account some non-official sources (e.g. blogs) and making a comparison with past Italian experiences, some mechanisms emerging within the recovery/reconstruction phase will be presented and recognized as drivers for further vulnerabilities, even in the face of a future disruptive event.

In respect to the phases of a disaster cycle, it is possible to state that nowadays the Abruzzo region is still in the recovery phase due to the fact that a real debate on reconstruction is still missing. Different ideas are arising on the topic even if they are essentially provided by cultural movements.

A formal shift from the emergency to the recovery phase was achieved by the transfer of the official responsibility from the Commissioner for Emergency, Mr. Bertolaso (Head of the Italian Civil Protection), to the governor of the Abruzzo Region, Mr. Chiodi, as Commissioner for reconstruction. This occurred on the 1st of February 2010.

In the aftermath of the earthquake, most controversies grounded on the delay with which the new building codes, paying specific attention to seismic actions, had come into force. However, the scarce impact of new building codes on the existing building heritage was shown in the contribution on the Abruzzo earthquake in Del 2.1. In fact, they are related to new constructions and not to the existing building heritage that is critical for its major structural "fragility" (e.g. masonry building) and for being largely representative within the Italian building heritage. The resistance of some buildings is even more crucial when the structure at stake hosts a public function. A good example in the Abruzzo earthquake is the collapse of the Prefecture palace. This fact has shown how physical vulnerability turns into organizational vulnerability due to the competences the Prefecture is in charge of in terms of coordination of forces in the emergency phase.

Another "institutional" mechanism which has been recognized as an agent of carrying increased vulnerability was the absence of procedures of control during the phases of both realization and validation of a lot of buildings. This bad practice can have even higher consequences if the call for tenders to build such structures have been won by adopting the "Massimo ribasso"[13] criterion or, in other words, by choosing the bid with the highest discount on the starting price.

Under these circumstances, it is not rare, when implementing a control, that the quality of the structure (e.g. the choice of material, the consistency with the original design in terms of diameter or number of bars and so on) was compromised for economic reasons. In fact this has been confirmed by the investigations carried out on recently built structures in the city of

[13] It is worth referring that in the last December, the intention of excluding the "massimo ribasso" from the practices listed in the new regulation for public tenders has been announced, in order to prefer quality and not economy. (Available at http://www.denaro.it/VisArticolo.aspx?IdArt=583936&KeyW=inserto)

L'Aquila that collapsed. The most prominent case is the student dormitory that was also a public property[14]. The technical evaluation report, attached to the dossier prepared by the Public Prosecutor's Office (L.R.1) has in fact shown that part of the structure, in detail the Northern wing of the building, collapsed, due to the absence of a pillar, although the occurred shake has to be considered as "moderate". In this collapse, eight students died.

Other defects to be listed as a lack of the application of control procedures and paid with the life of eight young people are:

- The mistakes in the original design that did not consider horizontal strains generated at the occurrence of an earthquake, although law prescriptions were already in force ➔responsibility of the designer and of the public office in charge of the approval of the project;
- Lack of stirrups in the joints ➔ responsibility of construction company and of technicians devoted to control works and test the structure;
- Use of a scarce quality of concrete compared with what was prescribed by the project➔ responsibility of construction company and of technicians devoted to control works and test the structure;
- Absence of a functional adjustment in respect to the change of activities (residential, commercial) to which the structure was devoted ➔ entities responsible for the approval of the change;
- Bad realization of heating, electric and water systems ➔ responsibility of Construction Company and of technicians controlling works and testing the structure.

Hence, the scarce application of control actions by different actors has represented a form of institutional vulnerability that had a direct impact on the built environment, becoming in such a way a physical vulnerability, turned soon after, into a social vulnerability. A specific social group represented by students has in fact been affected by the collapse of the building. Students are very significant for the L' Aquila city, not only for the identity of the city (L'Aquila city was famous for being an important university pole) but also for being a core element of the economic system.

About half of the 27000 students before the earthquake were non-residential (CRESA, 2009). The condition of being "not resident" can constitute "per se" a factor increasing the vulnerability conditions for different reasons:

- A potential ignorance on the hazardousness of a given site. This fact can lead, for example, in respect to an earthquake, to undervalue the importance of the structural characteristics in terms of resistance of a building when choosing where to live, (e.g. by choosing according an economic criterion and not by its security);
- A major potential difficulty in taking decisions during the impact due to a scarce knowledge of places and local emergency orders in case of danger (e.g. point of gathering places);
- A major difficulty regarding the search of support from informal social networks (family and friends) available to provide hospitality and comfort in the relief time.

Furthermore, in terms of the transfer of vulnerability, it is worth considering that there is a huge turnover from students. A student represents in fact a source of income for all those people offering services (local transport, accommodation and food) to them. A potential decrease in the number of students in the whole (resident or not) has immediately disruptive effects in the economic sector.

[14] In detail, the student dormitory is a property of Abruzzo region even if managed by a private company.

For this reason, the major worry of the deans of the L'Aquila University at the reopening of the academic year was related to guarantee a sufficient numbers of "safe" accommodations, and to ensure other related services (e.g. canteens), for avoiding a decrease of students especially among the non-residential group.

If safe housing is an essential requirement for preserving the identity of the city as a university center, more generally, the demand for an accommodation is so high that the presence of not-damaged buildings has become the main "capital" since the emergency phase. The existence of houses that can be inhabited represents a source of speculation for the respected owners. The prices of property market, especially in the areas placed in proximity of the old town, have increased enormously. In such a way letting a flat near the old town has become a possibility to accumulate other forms of capital (e.g. money). Such a dynamic has been further exacerbated due to some choices of the Commissioner for Emergency: instead of repairing the flats recognized as only temporarily condemned, or, in other words, classified as "B" buildings according to the decree 2753/2009 on the census of damages, he has allocated all the human and economic resources toward the realization of the C.AS.E. plan[15]. No action has been made in terms of interventions able to restore these kind of buildings representing 13,2% of the whole analyzed building stock, even if in many cases there was only the need for measures which could be easily realized.

Not surprisingly, the big companies of the construction sector are getting advantage as a consequence of the earthquake and this fact is especially relevant if one considers the crises that affected the sector before the earthquake (CRESA, 2009). Also moving companies have increasing economic profits due to the continuous relocation of people from one place to another, also due to the decisions of the Commissioner[16]. In this case, it is possible to affirm that some groups are increasing their level of capital and, as a consequence, their adaptive capacity whereas adaptive capacity has been recognized as being an important aspect of resilience during the recovery phase (del.2.2). In this case it is not easy to identify categories of actors which are negatively affected by the attainment of resilience of such actors (construction and house moving company).

On the other hand, referring to the previously presented case of owners with not seriously damaged flats, it can happen that, the response and recovery abilities of other actors are weakened (fig. 1). Focusing only on houses due to the existing high demand and the corresponding higher value and income can divert from using resources for other activities, as for example, investing in new commercial activities that, in a more profitable manner, could drive the system to regain an acceptable level of functioning.

By this perspective, the big attention devoted to house demand, even if widely justifiable, can be interpreted as a removal of capital, especially in monetary terms, from the re-launch of local economy. Previous post-earthquake experiences have shown that re-establishing economic activities is an efficacious strategy for the process of reconstruction. Among these experiences, the reconstruction of the Friuli Region in the North of Italy, hit by an earthquake in 1976, is a good example. The reconstruction period has been in fact characterized by a strong impulse of local communities. This was probably influenced by the bad results of the Belice's experience, an area of Sicily hit only few years before (1968), attributable to the bad management of the Central Governor and to the complete exclusion of the local administration in the decision process. In the Friuli experience, only six days after the earthquake (Atlante Repubblica, 2009), small local businessman asked for receiving non public funds to re-launch activities in a rapid manner, avoiding in such a way the inertia and the time of central bureaucracy, because they were conscious that an effective

[15] The C.A.S.E. plan consists in building sustainable and eco-compatible buildings with given characteristics toward earthquake. They are not temporary shelters but definitive houses.
[16] For example, when all the tent shelter closed, a lot of people have been transferred to the hotel of the coast.

reconstruction was possible only thanks to the effort (also individual) and the work of the population.

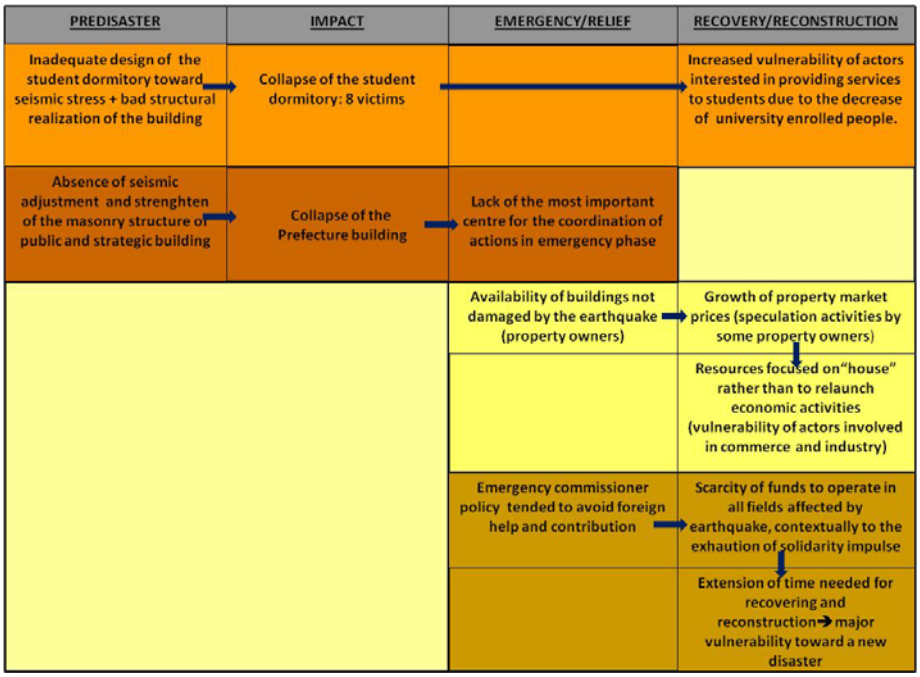


Figure 40: Examples of the transfer of vulnerability across time in the Abruzzo case

In the Abruzzo case, even if a tendency of creating associations is increasing, especially as private consortia for re-establishing commercial activities in the old town centre, the management of the earthquake aftermath has been, up to now strictly centralized in the hand of the organizational structure of the Commissioner for Emergency. In this respect, the population has shown a great solidarity based on the shared hard conditions of everyday life and with some exceptions (e.g. owners of houses not damaged by the earthquake) there is no proof of a transfer of vulnerability mechanisms from one group to others. Only as a consequence of the Commissioners' structure choices different conditions of people appeared: examples are people who were given the right to live in a C.A.S.E. plan house or people that were moved 80 km from the place where they lived, for example to a hotel of the coast). Another strong choice undertaken by the Commissioner Bertolaso that could have important reverberation in the future is related to the rejection of international aid, because, in his words, Italy is able to solve problems by itself (L.R.2).

In this respect, an extraordinary episode refers to the reconstruction of the Academy of music. An important Japanese architect, specialized in works in seismic areas, had prepared, without asking for payment, the design for the Academy. Additionally he promised to cover 2/3 of the whole costs through the NGO " The voluntary architects networks" whereas the 1/3 part should have been paid by the Japanese Government. The Commissioner rejected the proposal and preferred to realize a temporary construction that costs three times the price estimated for the Japanese project and has also a lower quality. Considering that there is an estimation of about 3 billion of euro (Il Centro) for restoring and repairing o part of the damaged Cultural Heritage (churches and palaces), it cannot be excluded that this demonstration of national proud will have consequences. These might be especially taking into account that, as shown in different researches (e.g. Cattarinussi and Pelanda, 1981), the solidarity impulse is not an inexhaustible dynamic and especially on tourism which was an essential strategic economic sector for all the area and for which cultural heritage is crucial.

Inevitably, after transfer of responsibility from the chief of Civil Protection, as Commissioner to Emergency, to the Regional Governor, as Commissioner for Reconstruction, it is supposed that more occasions of transference of vulnerability will arise. It is to be expected that local administration will receive pressures for pursuing different purposes proposed by different actors. A new equilibrium could occur with new unbalances in terms of a fair distribution of resources and means and the accessibility to both. These might have effects on the time needed for the effective recovery of individuals. Some threats linked to a misuse of the disaster recovery funds can be found in informal sources of information as blogs of newspapers. For example, the blog of "Il centro" (Il Centro, 2) dedicates an article to shrewd owners of building classified as A (usable) or B (temporary non-usable but usable after minor interventions) that have tried to convince engineers and architects to realize a technical plan which includes "aesthetics" of their property such as plastering, arrangement of the roof garden and so on. Furthermore the blog refers to some municipality councils inclined to support some requests proposed by "friends" at the expense of rational criteria.

The management of the forthcoming reconstruction is a very delicate issue. A lack of a rational use of funds can lead to an extension of the time needed for recovery. This might lead to the risk of an invisible overlapping between the recovery and the preparedness for the occurrence of a new disaster. In such a way, the failure of a return to an acceptable level of functioning in a reasonable time paralyzes the possibility of preparing tools to cope with a new event. Consequences might be worse than in the past due to the already deteriorated initial conditions.

To sum up, the analysis of the Abruzzo earthquake clearly shows the dynamic aspect of vulnerability across time in terms of transference from one typology to another and from some actors to others. This is especially true when the "scale" of the decision process changes, moving, for example, from the central level to the local level. In such conditions, more easily, some groups of people get advantages at the expense of others, determining new vulnerability patterns.

7. Conclusion

7.1 Coping/Response Capacity & Resilience: Temporal Variations and their Determinant Role on Vulnerability Evolution

It has been suggested already (in the context of Del. 2.1.2, p.81) that if Resilience is to be conceived as an operational property it might then be defined as *the ability of an actor or system (a) to develop inherent resources and means usable to response and recovery and/or (b) to extract means and resources from the physical, social, economic, political and ecological environment in order to engage and commit them consequently for the purpose of own response/recovery or for improving own position.* Besides, Deliverables 2.1.2 and 2.2 acknowledge that:

- Vulnerability and resilience may co-exist in the same system;
- Resilience is an attitude that affects positively the coping and response capacity of the system that exhibits such an attitude, meaning that this capacity depends greatly on resilience;
- Resilience functions as a determinant factor or a catalyst for vulnerability change, vulnerability transfer, transformation and re-balancing.

The findings of the present Del 3.1 improved our knowledge about resilience:

- Resilience is an issue depending on Risk Perception; this has been evident in the case of Guadeloupe (French West Indies) for example, which suffered in 2004 from a crisis including floods, landslides and a destructive earthquake. The remarks of the respective authors (Section 5.1.2, p.52) are eloquent in this sense:

  "In the West Indian society, where superstition, mysticism and fatalist beliefs prevail, the common attitude is generally passivity and wait-and-see…….people do not understand the need to prepare between successive events".

  Interdependence between resilience and risk perception is documented also in the case study of Acheloos river diversion where the widespread belief (among the communities of the Region of Thessaly) that engagement of Acheloos waters by the Region of Thessaly (at the expense of the Region of Aetoloakarnania) will rescue the there farmers from agricultural drought despite controversies between expert opinions, will finally determine the realization of a huge public investment in a controversial technical infrastructure.

- Resilience is the possibility of a system to attract the needed resources from the available in normal periods and extra post-disaster capital in order to cope with and respond to risks, losses or the needs of recovery, i.e. to build the response and coping capacity. In other words resilience may be interpreted as the accessibility of the exposed or hit system to the needed forms of capital. Indicative is the following extract from the case of Acheloos river diversion (Section 6.1.1., p. 81):

  "Adaptation to perceived economic and social vulnerability (to drought) demanded the use of natural, economic and political capital to mitigate vulnerability over a long temporal scale, marked by advances and retrogressions, power struggles and endless judicial litigation….".

  Indeed in this specific case the farming community of Thessaly seems to have higher accessibility to political power (i.e. higher resilience) and hence "block" Acheloos waters for their own needs to the disadvantage of Aetoloakarnania communities.

- As regards the evolution of resilience along a series of successive disaster events there are two distinct cases: (a) In case of ecological systems (and ecological vulnerability) the more frequent the successive events are the less their resilience (and response / coping capacity) turns to be; (b) in case of social, economic, territorial, institutional systems short time intervals between successive events may increase awareness (risk perception) and imply enhancement of resilience.

Shifting our attention now to the response/coping capacity of a system versus risk, vulnerability, losses and recovery prospects research in WP2 arrived at the following findings:

- The response and coping capacity of a system is a function of the available by the system and conveyable to response and recovery forms of pre- and post-disaster capital. In pre-disaster terms this is the committed to mitigation pre-disaster capital, in emergency and recovery periods this is the committed to response pre-disaster capital after losses plus post-disaster, extraordinary forms of capital (that are latent or non-existent in normal periods and emerge only in crisis situations). Hence:

  $ReCa = f(C_{predM})$ in pre-disaster terms and

  $ReCa = f(C_{pred\ -loss}, C_{postdRe})$ in post-disaster terms.

- According to ENSURE's definition of Vulnerability, response/coping capacity is one "leg" of vulnerability, the other is propensity to loss.

The present Report (in the context of WP3) shed light to the complex interrelations between coping/response capacity, exposures and susceptibility to loss; also how these interrelations evolve along the stages of a disaster cycle and a series of multiple cycles:

- All case studies evidenced that coping/response capacities interact with exposures and susceptibility to loss (see for instance Sections 5.1.1, 5.1.2, 6.2.1); an increased coping ameliorates exposure and susceptibility to loss while high exposures (and the resulting awareness) may increase coping capacity.
- However, and as indicated above coping/response capacity is affected also by resilience, i.e. accessibility of the vulnerable system to the appropriate forms and quantities of capital. What we have actually is a triangular form of interactions (figure 41).
- Coping/response capacity is a property which is present all along the disaster cycle; in pre-disaster terms coping capacity may mitigate exposure and susceptibility to stress/loss, in emergency and relief periods response capacity may restrict and control actual losses while in recovery periods this capacity determines the recovered losses and vulnerability to new stress (figure 42).

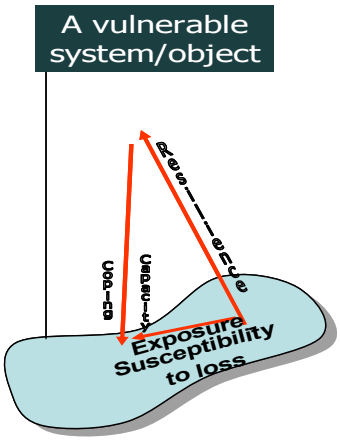


Figure 41: The mechanism changing vulnerability – Interactions between Resilience, Coping Capacity and Exposure/Susceptibility to Loss

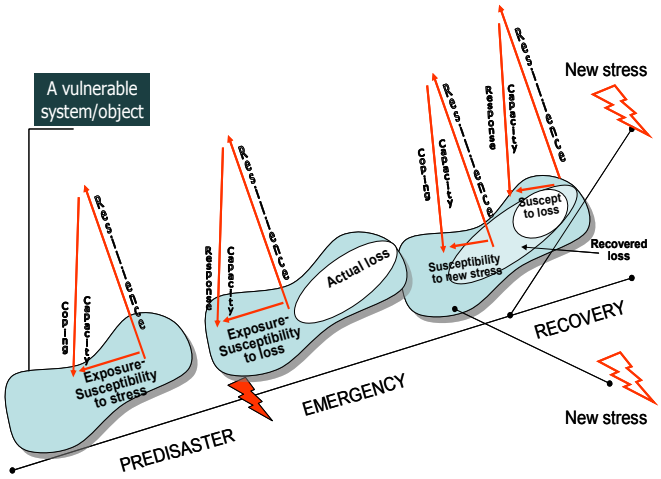


Figure 42: Interactions between Resilience, Coping Capacity and Exposure/Susceptibility to Loss all along the disaster cycle

It happens usually that the coping/response capacity component of vulnerability is inoperative in pre-disaster terms leaving exposure and susceptibility to loss to be determined by other than risk management practices, conditions and priorities. In general terms institutions and institutional vulnerability is the underlying factor determining the high or limited response/coping capacity of a social or economic sector, a whole community or territory. In this sense institutional vulnerability (as both "own potential for losses and incapacity to respond" and "incapacity for policy-making and operational performance in the field of risk management") is a generator and pointer of other forms of vulnerability (economic, social, physical, etc). This means that assessment of institutional vulnerability alone might represent a global study of vulnerability and integrated vulnerability indicators in the sense that these reflect also other vulnerability facets such as physical, social and economic.

7.2 Transferences, transformations and (re) balancing of vulnerability: Issues of scale

It has already been demonstrated that response/coping capacity is the basic means for vulnerability reduction. However, this is not a clear statement because it does not clarify "who" brings into effect vulnerability reduction, for the sake of "whom" and "where" does the discarded part of vulnerability wind up.

To answer the above queries the present report employs a new methodological approach, "the Vulnerability Actor or Agency approach", which is developed and turned into advantage by the case studies of Chapter 6. This methodology constitutes an alternative or additional option to the "Vulnerability Facets" approach which has been followed consistently since the beginning of the project.

In particular, this new approach assumes that the response/coping capacity is a property being developed by vulnerability carriers who/which are at the same time vulnerability managing systems or in other words "Vulnerability Actors". In particular the assumptions backing this new concept are as follows:

- ✓ "Vulnerability Actor" is an entity or system capable to change own and other systems' vulnerability; for this purpose an Actor employs own response and coping capacity (see Section 3.1);
- ✓ A Vulnerability Actor is a vulnerability managing system attempting to get rid of this undesirable property and influencing (and being influenced by), directly or indirectly, other Actors' vulnerability (see Sections 6.1.2 and 6.2.1);
- ✓ A Vulnerability Actor may target simultaneously vulnerability to several potential threats and/or multiple types of losses (e.g. economic, social, physical, functional losses and failures etc)(see Sections 3.1, 3.4.2, 6.1.1);
- ✓ Vulnerability Actors may be micro-or macro-scale Actors; they may be social actors (e.g. human individuals, households, population groups, communities), economic actors (e.g. firms, production sectors, regional economies), institutional actors (e.g. fire departments, local authorities, central governments), eco-human and territorial actors (e.g. the Jewish rural settlements of a Moshav and the rural settlements of Bedouins in Northern Negev, Israel –see Section 6.2.2);
- ✓ A Vulnerability Actor may carry several vulnerability facets. For instance, an institution normally carries institutional, but also physical and economic vulnerability, a firm economic, social, physical, functional vulnerability. An agricultural household living and cultivating in an area suffering from drought is faced with economic vulnerability (due to periodic loss of agricultural income), social vulnerability (due to for instance, shortage of water from domestic uses or a contingency of poverty as a

concomitant of loss of income) and physical vulnerability (due to the potential of impact on human health out of the use of water of low quality);

- ✓ A Vulnerability Actor uses own response/coping capacity to perform specific "functions": (a) Internal (re)balancing of own vulnerability facets, meaning control and restriction of certain facets leaving others to deteriorate, (b) Transformation /Transfer of certain facets to other actors, when for instance a region dispossesses another region from essential (for the environment and the regional economy) water quantities by means of a river diversion (see Section 6.1.1); (c) (Re)distribution to the disaster cycle stages (current and future) and (re)balancing between exposure and response capacity; (d) (Re)distribution between current and future hazards and (e) Receiving vulnerability from other Actors (see Section 3.4.2)(figure 43).
- ✓ An Actor's vulnerability refers always to the attached to or controlled by the Actor capital (human, social, economic, physical etc). It is this capital that is exposed and susceptible to losses, it is this capital that offers the resources which build the coping and response capacity of the Actor and it is the ability of the Actor to attract the additionally needed resources from pre-disaster and extra (post-disaster) capital that determines resilience.

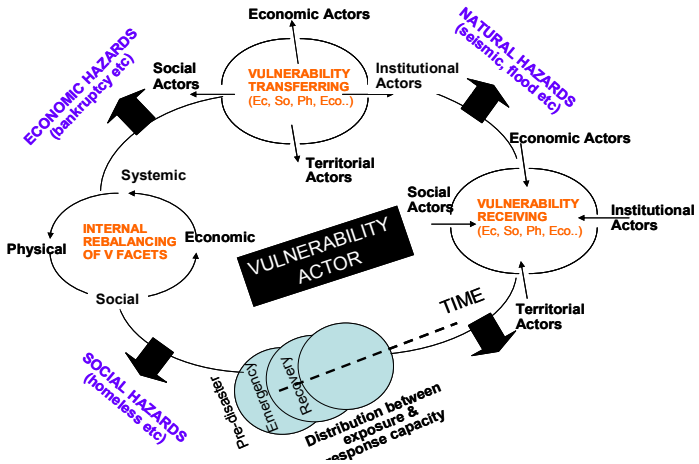


Figure 43: The "Functions" of a Vulnerability Actor

The above assumptions have been testified and more or less confirmed in the following case studies of the present report:

- The case of Acheloos river diversion as a response to the agricultural drought of Thessaly, Greece (Section 6.1.1);
- The case of flooding and chemical spillage following hurricane Katrina in St Bernard Parish, New Orleans, Luisiana, USA, in August 2005 (Section 6.1.2);
- The case of territorial / eco-human system of Leros (Dodecanese islands, Greece) aand the adhoc solutions given to its hydrological drought problem (Section 6.2.1);
- The case of territorial / eco-human system of Northern Negev (Israel) and the response of the Actors involved in its agricultural drought problem (Section 6.2.2);
- The mechanisms of vulnerability transference in the Abruzzo earthquake case (Section 6.2.3).

As a first step the authors of the above case studies identified the V Actors involved in each case (see Table 18 below referring to the first four of the above cases).

Table 18: Vulnerability Actors involved in specific territories and Risk/Disaster cases

ACHELOOS RIVER DIVERSION AND THE AGRICULTURAL DROUGHT OF THESSALY, GREECE	FLOODING AND CHEMICAL SPILLAGE FOLLOWING HURRICANE KATRINA IN ST BERNARD PARISH, NEW ORLEANS, USA, AUGUST 2005	THE TERRITORIAL SYSTEM OF LEROS (DODECANESE ISLANDS, GREECE) FACING HYDROLOGICAL DROUGHT	THE TERRITORIAL SYSTEM OF NORTHERN NEGEV (ISRAEL) FACING AGRICULTURAL DROUGHT
- Central government in Athens - Local organizations of the regions of Thessaly and Aetoloakarnania (prefectures, municipalities, rural cooperatives, trades unions and producer chambers) - The Council of State (Athens) - National Environmental NGOs - Political Parties and politicians - The European Commission - Consumers & taxpayers	- The local population of St Bernard Parish - The multi-national Murphy Oil Company - Insurance companies - Federal Government; FEMA; State Emergency Response Organizations; US Army Corps of Engineers - NGOs - Neighbouring communities and States - Other regions in which Murphy operates	- DEYAL, the local company of water supply, Leros - The Prefectural Department of Land Reclamation Works, Rhodes - Ministry of Agriculture (Athens) - Lawful public water consumers in leros - Illegal structures for water procurement and supply	-Jewish farmers in Northern Negev - Bedouin farmers in Northern Negev - Mekorot (state owned company responsible for the water supply to agriculture - Ministry of Agriculture, Tel Aviv - Ministry of Finance

It is evident from the table that the involved V Actors are not only those located in the exposed or stricken territory but also higher level Actors being seemingly out of the range of the threat. Indeed, response capacity and vulnerability levels of the exposed Actors and territories come about as the composite result of various multi-level decisions and interactions extending beyond the geographical range of the exposed areas and including non-exposed Actors too.

As a second step the authors localized and identified the resources employed by the V Actors in order to manage their vulnerability. These were both on the spot close resources and others located far away beyond the area bedeviled by the hazard (but which fell within the range of control of the V Actors). For instance, the Murphy Oil Company (after the chemical spillage caused by flooding following hurricane Katrina) appealed to the US Environmental Protection Agency (EPA) and the US Coast Guard (regional level) to deal with the oil spillage; it also appealed to global resources as a multi-national corporation (global level); it took advantage besides of government tax-bonds (national level) after Katrina to support own repairs and reconstruction. To refer to another example the local organizations of the Region of Thessaly in Greece (municipalities and prefectures, rural cooperatives, trades unions and producer chambers) used their lobbying power over central government to secure public investments (i.e. resources of the national level) in Acheloos river diversion works (dams, reservoirs and irrigation networks).

Interaction between several spatial scales and institutional levels is also evident in the third step of the Vulnerability Actor approach. Transferences, redistribution and vulnerability receptions cover indeed extended spatial, temporal and institutional ladders. In the case of Northern Negev the Ministries of Agriculture and Finance bear the responsibility of demarcating areas prone to droughts where farmers receive compensation during the drought years, mitigating in this way social and economic vulnerability of certain areas and communities (inside the drought lines) and transferring vulnerability to those outside the drought lines. In the case of post-disaster response by homeowners and business people of St Bernard Parish, whose properties were contaminated, those who managed through legal action to receive financial compensation by the Murphy Oil Company they transferred part of their costs and vulnerability to the company's shareholders and employees globally.

In general terms the steps of the methodology of V Actors assessing the impact of their action (and functions) on own and others' vulnerability are summarized in the following diagram (figure 44)

However, in a time continuum it is difficult to capture initial vulnerability (step 2 of the methodology). It is much more easy and practical and much more policy relevant to capture entities and agencies being in a course of vulnerability increase. Therefore, step 2 of the methodology could be omitted.

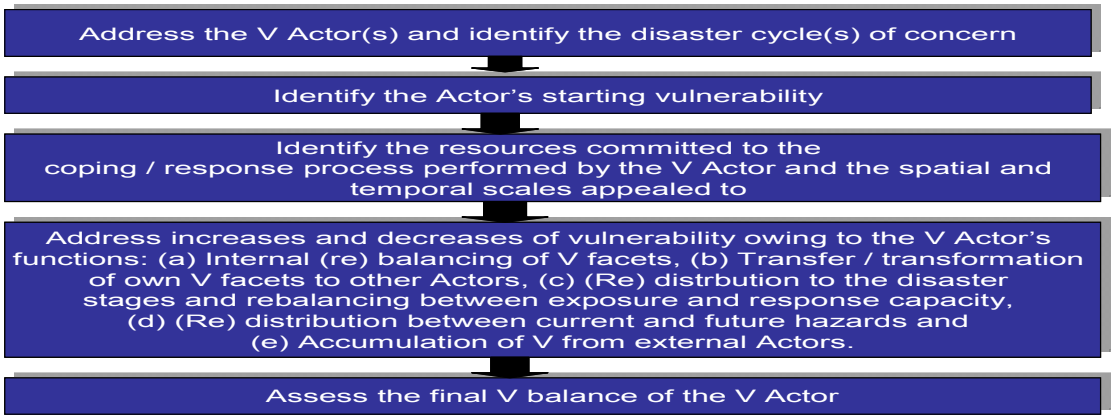


Figure 44: The steps of the "Vulnerability Actor" approach

7.3 Opportunities for vulnerability assessment and integration on the basis of natural, financial, physical, social, human and territorial capital

Vulnerability is a relational property; what matters is comparison between actors, places etc; what matters is who / which is more and who / which less vulnerable. This allowed the authors of Section 4.1.2 about economic vulnerability of the local population of St Bernard Parish to build three 7-point categorical scales for describing vulnerability, which are in detail: (a) a depth of vulnerability scale (DV) from DV1 (minor) to DV7 (extreme), (b) a capacity to recover scale (R) from R1 (none, virtually none) to R7 (excellent) and (c) the above together, i.e. recovery capacity and depth of vulnerability (DRV) joint scale ranging from DRV1 (minor) to DRV7 (extreme).

Another possibility is to distinguish cases of vulnerability according to the type of carrying system (e.g. on the one hand physical and technical systems and on the other social, economic, institutional and territorial) or according to the stages of a disaster cycle. Regarding this second option we can distinguish between:

- A system's vulnerability in pre-disaster terms which is manifested as exposure;
- A system's vulnerability in the disaster phase which is manifested as susceptibility to stress;
- A system's vulnerability in the emergency-relief phase which is manifested as (a) actual losses, (b) susceptibility to loss (potential for further losses), (c) (in)capacity to respond;
- A system's vulnerability in the recovery-reconstruction phase which is manifested as (a) (in)capacity to recover losses, (b) generated exposures and susceptibilities to new stress (new hazards or future events).

With respect to the above we already know that:

- ✓ Only physical and ecological vulnerability are cases of vulnerability to stress; all the rest (economic, social, institutional, territorial) are cases of vulnerability to loss (see Del 2.1.2 conclusions);
- ✓ Vulneraibility to stress is a function of hazard characteristics, $V_{str} = f(H)$; Vulnerability to loss is a function of vulnerability to stress and the respective thresholds of losses (see Del 2.1.2 conclusions), i.e. $V_{loss} = f(V_{str})$ or $V_{loss} = f(L_{thres})$.

Exposure and its relationship with susceptibility to stress and loss is a tricky issue; when exposure is considered as a wider term implying not only geographical location (in relation to the stress and losses) but also hierarchical positions in social, economic, knowledge, technological etc hierarchies or ladders, then the two terms (exposure and susceptibility to stress/loss) overlap (see also Cannon et al 2003). This means that technological, social, economic, ecological ladders (referring to the specific hazard under consideration) and the position of the exposed to hazard system or element in these ladders may offer a measure of its susceptibility to stress/loss (figure 45)

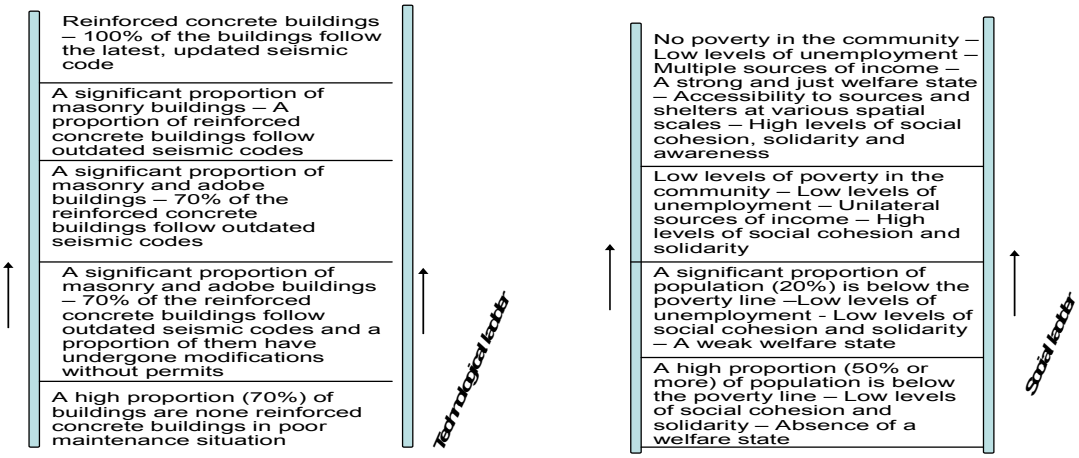


Figure 45: Examples of ladders measuring susceptibility to loss (technological and social) in the case of seismic hazard threatening an urban territory

Finally, the anatomy of coping / response capacity is given by the Functions of Vulnerability Actors (see figure 45). However, in order to perform these functions the V Actors or vulnerability carrying systems need resources (i.e. specific forms and quantities of capital). Therefore, successful performance of the V Actors' functions depends on the availability of the needed capital (pre- and post-disaster). The needed resources depend, of course, on the type of the V Actor or system. If for instance, the V Actor is a household its response or coping capacity depends on such resources as property assets, income sources, risk knowledge and disaster experience, accessibility to social and political support etc. But the needed resources vary also in relation to the type of the function that has to be performed. Thorough study and investigation of the accessible (and inaccessible) by the V Actor resources seems to be equivalent to a study of projection / anticipation of the degree of performance of the Actor's functions and of their success. This assessment of accessible resources and conveyable to response and recovery offers a measure of the coping/response capacity of the Actor/system which of course increases / decreases in the course of time (see tables presenting the resources engaged in the performance of V Functions, Sections 6.1.2 and 6.2.1). It is certain that the Actors and systems with limited accessibility to resources will be burdened with always increasing vulnerability levels.

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Appendices

Table I: Vulnerability landscape for the local parish population of St Bernard Parish according to disaster phases, focusing on economic vulnerability in the Katrina flood and subsequent chemical spillage disaster

Type of vulnerability categorised as: V1 (Susceptibility to stress); V2 (Susceptibility to loss, or potential for loss); V3 (Vulnerability manifested as actual loss); R (Capacity to recover)

Vulnerabilty categorical scales: Pre-disaster and disaster phase depth of vulnerability scaled as: DV7 (Extreme); DV6 Very Severe; DV5 Severe; DV4 (Serious); DV3 (Less than serious); DV2 (Moderate); DV1 (Minor). Recovery capacity scaled as: R7 (None or virtually none); R6 (Very severely limited); R5 (Severely limited); R4 (Impaired); R3 (Less impaired); R2 (Good); R1 (Excellent. Emergency relief and recovery and reconstruction phase recovery capacity plus depth of vulnerability scaled as: DRV7 (Extreme); DRV6 (Very severe); DRV5 (Severe); DRV4 (Serious); DRV3 (Less than serious); DRV2 (Moderate); DRV1 (Present but minor).
Where resilience is indentified as an intervening factor or process, this is denoted by a blue R. Comments about resilience are also in blue and often apply to a segment of population, and to all facets of vulnerability for a particular disaster phase, but are only entered once.
Comments on **propagation of losses to different scales** are in red.
Principal significant facet impacts on other facets are indicated by orange arrows e.g.

Local parish population segment (not mutually exclusive segments) Those who: -	Vulnerability facet	Phase of disaster			
		Pre-disaster: before August 2005	**Disaster: August 2005**	**Emergency relief: August 2005 – January 2007**	**Recovery and reconstruction: after January 2007**
		Description of predominant vulnerability			
died in the disaster (including those who decided to sit out the storm and the less mobile segment of the population)	**Economic**	V2 DV6 but perceived more as DV1 or DV2 Potential for injury and loss of income earning capacity; loss of value of property and possessions, property blight. R. Evacuation plans and some with flood insurance.	V3, DV7 Life lost – total unrecoverable loss; income earning capacity lost; property and possessions lost.	Inapplicable - life lost in flood disaster – failed to evacuate or died as a result of flood R. Failed attempts at being resilient (i.e. to ride out the storm). Evacuation plans not taken seriously	Inapplicable – life lost in flood disaster – failed to evacuate or died as a result of flood
	Social	V2 DV5 Potential for injury or loss of life; and for loss of community and of social support systems	V3, DV5 Life lost – total, unrecoverable loss	Inapplicable - life lost in flood disaster – most failed to evacuate	Inapplicable – life lost in flood disaster – most failed to evacuate

	Physical	V1, V2, DV5 but not perceived as such Potential for loss of property and possessions. R. These residents boarded up their homes, move belongings, bought food and water (Hauser et al., 2008)	V3, DV7 Severe property damage and loss of possessions	Inapplicable - life lost in flood disaster – most failed to evacuate	Inapplicable – life lost in flood disaster – most failed to evacuate
	Institutional	V2 DV4 Widespread institutional failures exacerbate all other vulnerabilities above for this population segment, but the only cause	V3, DV4 Institutional vulnerabiliity translated into loss of life – total unrecoverable loss but not the only cause	Inapplicable - life lost in flood disaster – most failed to evacuate	Inapplicable – life lost in flood disaster – most failed to evacuate
are suffering from a disability either related to employment, transportation or self-care, who are also survivors	**Economic**	V2 DV6 Earning ability likely to be impaired, likely to be economically dependent with R. some financial support. Evacuation Plans	V3 DV6 Dependent on others, some evacuated R. care support and evacuation plans	R3 DRV 7 R. Financial aspects of care systems provide financial support and recoverability. Susceptibility to further loss is very high.	R2 DRV6 R. Financial aspects of care systems provide financial support and more recoverability with time. Susceptibility to further

					loss is high.
	Social	V2 DV6 R. Members usually had some social support	V3 DV6 Support systems fragmented, social networks lost	R5 DRV7 Loss of social networks and support. R. welfare support.	R4 DRV6
	Physical	V1, V2 DV6	V3 DV6	R5 DRV7	R4 DRV6
	Institutional	V2 DV5 Widespread Institutional failures and failure to complete the evacuation planning for disabled.	V3 DV5 Widespread Institutional failures and failure to complete the evacuation planning for disabled.	R5 DRV7	R5 DRV7
are family members of those who died (and who might suffer vulnerability changes owing to death of family member). **These members would**	**Economic**	V2 DV6 Unless breadwinner, financial consequences are likely to be small or could even be positive (family members may receive legacy).	V3, DV6 Financial consequences of family member's death are likely to be small. However, if the dead person is the main breadwinner,	R2-R5 DRV7 Financial deprivation unlikely and therefore ability to recover from economic vulnerability is likely to be a minor issue, unless main	R1-R2 DRV6 Financial deprivation unlikely and therefore ability to recover from economic vulnerability is likely to be a minor issue, unless main

mostly have evacuated and returned over time, although some may have resettled permanently elsewhere (see below). **The vulnerability takes into account their own vulnerability to loss.**		At risk themselves R. Some residents had flood insurance	family members can be more vulnerable.	breadwinner R. Insurance payout for some	breadwinner but time to adapt.
	Social	V2 DV4 to DV6 Being left as a dependent. Bereavement potential	V3, DV4 to DV6	R3-R5 DRV7 if returned R. Family members drew on family solidarity to get them through the loss	R2 or R4 DRV6 If returned R. Family members drew on family solidarity to get them through the loss
	Physical	V1, V2 DV64 – DV2 or DV1 DV4 where family member lives in same home, DV2 or DV1 if not R. Resilience existed in the form of evacuation plans which saved the lives of many. However, many took evacuation plans lightly (Hauser et al., 2008)	V3, DV4 or DV2 or DV1 DV4 where family member lives in same home; DV2 or DV1 where they live in a different home either in the community or elsewhere This vulnerability can propagate to other scales/locations almost anywhere in the US or beyond	R5 for a family member who lives in same home, or R1 if family member lives elsewhere DRV7 if returned This vulnerability can propagate to other scales/locations almost anywhere in the US or possibly beyond	R4 As a result of court action or voluntary financial settlements DRV6 if returned
	Institutional	V2 DV3 Widespread institutional failures exacerbate all	V3, DV4 Widespread institutional failures	R2 –R3 DRV5 if returned	R2 – R3 DV4 to DV2 if returned.

		other vulnerabilities above for this population segment	exacerbate all other vulnerabilities above for this population segment		Some institutional learning assumed thereby reducing risks of repeat failures
resettled permanently in another location (this is assumed to have low risk of natural and na-tech disaster)	**Economic**	V2 DV6 but perceived more as DV1 or DV2 Potential for injury and loss of income earning capacity; loss of value of property and possessions, property blight. R. Some had flood insurance.	V3 DV6 to DV3 The degree to which homes and businesses were damaged by the flood and also by the oil contamination varied. This variance is encompassed here by the range DV6 to DV3.	R7 to R5 DRV3 to DRV4 These people drew on their own resources in the main to adapt and successfully adapted by relocating permanently and setting up a new life. R. Insurance payout.	R4-R3 DRV2 These people's ability to recover was by now probably good in most cases (but maybe not all). Most will have received financial compensation significantly increasing their financial ability to recover.
	Social	V2 DV6 Potential for injury or loss of life; and for loss of and social support systems	V3 DV6 to DV4 No loss of life but major loss of community and social support systems. People would have varied in the depth of their vulnerability.	R2 to R4 DRV3 or DRV4 By permanently resettling away from the devastated community these people set about reconstructing their social networks and support systems demonstrating their ability to recover. R. Accessed voluntary aid and assistance	R1 DV2 Financial compensation received may well have reduced stress and anxiety problems and related ill-health issues for these people reducing their personal health vulnerability.

				Scale impact.	
	Physical	V1, V2, DV6 but not perceived as such Potential for loss of property and possessions. R. Protected home by boarding up, also moved belongings and bought food and water	V3 DV6	R4 to R3 DRV2 Once a new home found in another location physical vulnerability evaporates Relocation to other areas is a scale effect.	R32 to R2 DRV1 Once a new home found in another location physical vulnerability evaporates Relocation to other areas is a scale effect.
	Institutional	V2 DV5 Widespread potential or latent institutional failures exacerbate all other vulnerabilities above for this population segment	V3 DV5 Widespread actual institutional failures impacted on all other vulnerabilities above for this population segment	R4 DRV4 to DRV3 Institutional barriers to resettlement may have had to be overcome by resettlers	R3 DRV1 to DRV2 Once resettled and compensated financially, most institutional barriers causing vulnerability evaporate
returned to the community after the disaster	**Economic**	V2 DV6 but perceived more as DV1 or DV2 Potential for injury and loss of income earning capacity; loss of value of property	V3 DV6 to DV4 The degree to which homes and businesses were damaged by the flood and also by the oil contamination varied. This variance is	R5 (maybe R4 for some) DRV7 Loss of employment source and income for some, but not for others. Difficulty in persuading	R3 to R1 DRV6 The effect of financial compensation reduced significantly financial vulnerability increasing ability to recover

		and possessions, property blight. R. Some had flood insurance.	encompassed here by the range DV6 to DV4. Source of employment devastated for some and so loss of income source.	oil company to compensate voluntarily at least initially. Many lost all their possessions and home, and with it the basic equipment to recover. Utilities slow to be fixed. Voluntary assistance began to be provided, also help from family members in some cases. R. Insurance payout.	
	Social	V1, V2 DV6 Potential for injury or loss of life; and for loss of and social support systems	V3 DV6 – DV4 No loss of life but major loss of community and social support systems People would have varied in the depth of their vulnerability.	R6 to R4 DRV7 Loss of community negatively impacts on ability to recover. Adverse health impacts felt. R. Accessed voluntary aid and assistance Scale impact.	R4 to R2 DRV5 Some finding it easier to recover as time passes and financial compensation is received, but the community is only slowly recovering
	Physical	V1, V2, DV6 but not perceived as such Potential for loss of	V3 DV6 to DV3	R6 to R4 DRV7	R4 to R2 DRV5

		property and possessions. R. Protected home by boarding up, also moved belongings and bought food and water. Also some had flood insurance.			
	Institutional	V2 DV5 Widespread potential or latent institutional failures exacerbate all other vulnerabilities above for this population segment	V3 DV5 Widespread actual institutional failures impacted on all other vulnerabilities above for this population segment	R6 to R5 DRV5 For many legal barriers were in the way of reducing all other vulnerability facets, and institutional response to the disaster was slow and faltering, especially initially	R4 to R3 DRV5 Once legal barriers to compensation removed and the institutional response to the disaster intensified, all other vulnerabilities reduced and ability to recover improved.

are yet to return to the devastated community	Economic	V2 DV6 but perceived more as DV1 or DV2 Potential for injury and loss of income earning capacity; loss of value of property and possessions, property blight. R. Some had flood insurance.	V3 DV6 to DV4 The degree to which homes and businesses were damaged by the flood and also by the oil contamination varied. This variance is encompassed here by the range DV6 to DV4.	R7 to R5 DRV3 Insufficient is know about this group but some did not return because they could not face doing so, or were unable to because accommodation and services were too poor in the devastated community. Others might have been relatively comfortable and prepared to wait for their return. R. Insurance payout.	R5 to R3 DRV3 Financial compensation will have reduced depth of vulnerability but ability to return remains hampered possibly by social and psychological factors
	Social	V2 DV6	V3 DV6 to DV4	R6 to R3 DRV5 R. Accessed govt.and voluntary aid and assistance. Scale impact.	R4 to R2 DRV4
	Physical	V2, DV6 but not perceived as such R. Protected home by boarding up, also moved belongings and bou food and water	V3 DV6 to DV5	R6 to R3 DRV5	R4 to R2 DRV4
	Institutional	V2	V3	R3	R3

		DV5	DV5	DRV5	DRV5 to DV3
are local business owners	Economic	V2 DV6 Threat of business being physically damaged leading to loss of business and potential bankruptcy. R. Some had flood insurance	V3 DV6 to DV4 The degree to which businesses were damaged by the flood and also by the oil contamination varied. This variance is encompassed here by the range DV4 to DV3.	R6 to R4 DRV7 Businesses lost some of their employees and many of their customers as the population of the community plummeted downwards after the disaster. R. Insurance payout.	R5 to R3 DRV6 Businesses varied widely in their ability to recover, some getting back into business and selling to employees of repair contractors and volunteers, whereas others could not do this. Financial compensation aided recovery ability.
	Social	V2 DV6	V3 DV6 to DV4	R6 to R4 DRV7 R. Accessed voluntary aid and assistance. Scale impact.	R5 to R3 DRV6
	Physical	V1, V2 DV6 but not perceived as such R. Protected home by boarding up, also moved belongings and bought food and water	V3 DV6 to DV4	R5 to R4 DRV7	R4 to R2 DRV6
	Institutional	V2 DV5	V3 DV5	R4 DV5	R4 to R2 DV4
are oil company	Economic	V2	V3	R4	R3

employees		DV6 Potential for major damage to refinery and shut down, with company laying off employees as a result. R. Some had flood insurance.	DV6 Minor losses to employees, in fact income from refinery to employees increased because of overtime required to get refinery back into operation but severe damage to homes.	DRV6 Employees faired better than others and maintained their income source, but still faced financial ruin if not insured for property damage. R. Insurance payout.	DRV5 Financial compensation and insurance payouts for some lessened the vulnerabilities
	Social	V2 DV6	V3 DV6 – DV4	R5 to R3 DRV7 to DRV6 R. Accessed voluntary aid and assistance. Scale impact.	R4 to R2 DRV4
	Physical	V1, V2, DV6 but not perceived as such R. Protected home by boarding up, also moved belongings and bought food and water	V3 DV6 to DV5	R6 to R3 DRV5	R3 DRV4
	Institutional	V2 DV3	V3 DV2	R5 DRV3 Some support received from oil company	R5 DRV2 Some support received from oil company

Table II: Murphy Oil Corporation: (a) initial, (pre-disaster) vulnerability, (b) actual vulnerability manifested by losses, and (c) subsequent post-disaster vulnerability

Vulnerability facets / ***Stages of the disaster cycle***	***Physical***	***Social***	***Economic***	***Systemic***	***Institutional***
Initial, pre-disaster vulnerability	*Potential for physical damage because Murphy oil refinery is located in exposed floodplain, but protected by flood levees.*	*Potential for loss of life and physical injury to employees.*	*Potential for loss of oil production and for costs of repairing physical damage caused by hurricanes and floods.* *Ability to recover is relatively robust: Murphy Oil is a multi-national oil company with operations around the world. It is able to cushion the impacts of weather-related disasters in one region by profits from other regions.*	*Potential negative financial impact on Murphy Oil company performance and loss of production in the Gulf of Mexico with impacts on the US economy.*	*A potential existed for flood levee breaching as the levee systems built by the US Army Corps of Engineers, the industrial river channel and diversions, seriously reduce the damping effects of the native marshland on flood surges.*
Actual vulnerability manifested by losses in the disaster	*Medium level of vulnerability: 'minimal' physical damage reported by Murphy Oil to the oil refinery in St Bernard parish (http://www.encyclopedia.com/doc/1P1 -12714770.html) following hurricane Katrina and despite subsequent flooding of the facility as the levees breached.* *While repair to part of the plant's electrical equipment and instrumentation, as well as a general cleanup of the facility, proved necessary, the refinery appears to have sustained no major damage from the storm according to Murphy Oil.*	*No loss of life or physical injury to employees reported by Murphy Oil.*	*Oil production shut-down at Meraux oil refinery until mid-2006.* *US Congress 'Gulf 'Opportunity Zone' financial aid available to encourage oil industry recovery.*	*Murphy's overall refining and marketing operations generated $131.6 million in 2005 and $110.6 million in 2006; increasing to $205.7 million in 2007. The decline in earnings after 2005, and the 86% revenue increase in 2007 was primarily due to higher repair costs and lower crude oil volumes at the company's Louisiana refinery 2006. In late August 2005, the Meraux refinery in Louisiana was damaged by severe flooding and high winds from Hurricane Katrina and was shut down for repairs until mid-2006. Total Hurricane Katrina expenses, after taxes, for refining and marketing operations were $1.9 million in 2007, $67.1 million in 2006 and $28.7 million in 2005; the sharp drop in 2007 spending means the company had essentially recovered from the*	*The US Army Corps of Engineer's flood protection system for New Orleans is considered to be flawed (National Academies, 2009), contributing to the physical damage and loss of production at the Meraux refinery.* *Local levee boards failed to adequately maintain the flood protection system.*

				effects of the hurricane (http://www.wikinvest.com/stock/Murphy_Oil_(MUR)). *Oil production and refining in the Gulf of Mexico severely disrupted by hurricane Katrina (Robin-McCaskill, 2006).*	
Subsequent post-disaster vulnerability	*Level of exposure and vulnerability currently remains as pre-Katrina, but standard of flood protection afforded by US Army Corps of Engineers likely to be significantly higher after 2011 as a result of Katrina.*	*Potential for loss of life and physical injury to employees.*	*Murphy Oil remains vulnerable to weather-related disasters such as hurricane Katrina, but is able to use its multi-national profit-base to cushion losses. Also the US Congress has a large stake in encouraging oil companies to remain located in the Gulf of Mexico and is prepared to financially aid recovery.*	*As above: company recovered by 2007.*	*The company remains dependent upon the US Army Corps of Engineers and local levee boards for protection against hurricane-related flood surge.*

Table III: Local population of Chalmete and Meraux: (a) initial, (pre-disaster) vulnerability, (b) actual vulnerability manifested by losses, and (c) subsequent post-disaster vulnerability

Vulnerability facets / Stages of the disaster cycle	***Physical***	***Social***	***Economic***	***Systemic***	***Institutional***
Initial, pre-disaster vulnerability	*A potential existed for physical loss of properties and the oil refineries owing to hurricane, flood surge and a na-tech (oil) event.* *However, houses, local business premises and the oil refineries were protected from hurricane-related flood surge by levees (but the optimism in the level of protection was too high).*	*Perceived potential of risk to life from hurricane, flood and na-tech event.* *Some anxiety owing to several oil refinery fires and population evacuations in the parish prior to Katrina.* *Also some level of concern about the oil refineries being a terrorist target.*	*Chalmete and Meraux are predominantly independent, blue-collar (i.e. manual labor,) low-income communities comprising descendants of migrants from the Canary Islands in the 1700s; 'white flight' settlers from the suburbs of New Orleans in the 1950s and 60s; and deep-rooted black communities.*	*A potential existed for loss of life-lines in a hurricane and flood event.* *A potential existed for Greater New Orleans to be severely damaged by hurricane and flood, so that the regional economy and not just the local economy of St Bernard's parish would*	*A potential for na-tech disaster existed in the Louisana oil industry sector prior to Katrina particularly as the industry already had a record of chronic, severe accidents. Ten of the State's oil refineries reported 2,116 accidents resulting in toxic releases, many near to schools and*

	In the oil storage tank farm, each oil tank was surrounded by a low earthen oil spillage containment embankment - to reduce the oi l leakage and spillage risk.	*Local social capital (e.g. social networks and support systems) were relatively well developed in this community with many long-term residents and local business owners. The pre-Katrina community is described as a 'tight-knit' one. Generations of families lived within blocks of each other forming close community support networks.*	*Much of the employment in the community was in one oil refinery or the other, and indirect economic effects of the oil refineries were also significant to the local community (e.g. local sales to employees).* *Some home and business owners did not possess hurricane/flood insurance (some informed that they did not need it by insurance agents), weakening their potential to recover from a disaster (http://www.corpwatch.org/articke .php?id=13883).*	*be hard hit.*	*residential neighborhoods, between 2005 and 2008 (http://yubanet.com/usa/Louisiana-Refineries-Report-Chronic-Severe-Accidents-Statewide.php).* *A potential existed for flood levee breaching as the levee systems built by the US Army Corps of Engineers, the industrial river channel and diversions, seriously reduce the damping effects of the native marshland on flood surges.*
Actual vulnerability manifested by losses in the disaster	*Heavy flood damage to most buildings including 20,247 (13,748 classed as severely damaged) houses: many floated off foundations. The levees breached causing up to 4.3m depth of flooding for duration of about 2 weeks (Bostic and Malaison, 2008).* *The earthen containment banks around each oil tank in one of the refineries were overtopped by floodwater. One oil tank floated and came to rest on unstable ground, causing a major uncontained leak.* *1700 properties contaminated by the oil spillage:* • *114 heavily contaminated* • *286 medium contamination* • *1300 lighter contamination*	*Major loss of human capital: 129 people died in St Bernard parish during the hurricane. Another 19 residents died elsewhere and another 6 were never found.* *Post-Katrina community is unrecognizable. Major loss of community and social capital as social networks and support systems were devastated by deaths, migration of most of the population out of the community (leaving it at first as a ghost town), and slow recovery of population through returns. Between July 2005 and February 2006 the population of St Bernard parish declined by 82.11% (Bostic and Malaison, 2008).* *However, 'new' social capital arrived in the community in the form of numerous minor to major acts of charity. An example is the Church of the Brethen Disaster Response Chalmete Project in which volunteers helped people transfer to trailers and helped with insulating and dry-lining properties. These volunteers helped families rebuild supplies and aided their recovery. Other*	*The refineries were able to return to work rapidly after the disasters, providing continuing employment to some of those who returned.* *Recovery potential of some homeowners and business owners limited by lack of insurance.* *People received charitable support in the form of free labor provided by church organizations which allocated funds for volunteer's travel expenses, leadership training, tools and equipment, building supplies and food and housing (http://www.brethren.org/site/News2?page=NewsArticle&id=7539)*	*Greater New Orleans and its economic capacity severely impacted by the hurricane and flood surge, with weakening trickle down effects on the local economy of St Bernard's parish.* *Roads and utility services (street lighting, power supplies, gas hook-ups, telecommunications) all very badly damaged by the hurricane disaster.* *Hospital services also lost and slowly recovering.*	*Murphy Oil was proved negligent in a legal case: its shortcomings severely and adversely affected the communities of St Bernard parish.* *The US Army Corps of Engineer' s flood protection approach is considered by many to be seriously flawed, contributing to the loss of life and heavy damage in St Bernard parish.* *The Federal Emergency Management Agency (FEMA) was also slow to respond to events.*

		volunteers established 'blogs' to enable people to share their emotional experiences and to work through their angers and anxieties. The Federal government also allocated funds for emergency shelters in Chalmete. *The catholic and private school sector was completely destroyed in Katrina, and all other schools closed down.*			
Subsequent post-disaster vulnerability	*4,000 homes and businesses demolished by August 2007, another 2,000 condemned.* *The levees were repaired but major improvement to the standard of protection not available until 2011.*	*Many residents who opted to stay in the community after the event were provided with trailers (i.e. mobile homes), but some still waiting as late as March 2006. By August 2007, 5,000 parish residents are in trailers.* *Parish population is 30,000 by August 2007, whereas it was 66,000 pre-Katrina. People became homeless, some lived with relatives elsewhere, others found housing elsewhere.* *Many residents are now very uneasy and anxious about living near the oil refineries and the risks that they pose. Murphy plans to expand its oil refinery at Meraux on land bought-up after the disaster causing more anxiety.* *Two years after the disasters, the school enrolment is 4,400, about half of the enrolment before Katrina.* *Long-term contamination of the communities poses a long-term health risk.* *Very significant Ill-health effects of Katrina(including the oil spillage and subsequent law suit) are reported as widespread among the local population:* • *livelihoods lost causing anxiety*	*$330m financial compensation paid to 6,500 properties owners by Murphy after successful law suit which proved negligence.* *Local economy seriously weakened and in slow recovery: the parish's workforce was 350 by August 2007 (2 years after Katrina) compared with 650 in the pre-Katrina period.* *Property blight: collapse of property values as the community has many derelict buildings and is a known contaminated one with long term contaminant residues. 600 property buy-outs offered by Murphy Oil to local residents as result of successful law suit against Murphy.* *Uncertainty over the future of the community and whether it will be redeveloped.* *Insurance companies decided not to sell insurance in the community after the events, and so local residents faced with paying two to three times as much for insurance through Louisiana Citizens Property Insurance Corp thereby raising the cost of home ownership (Bostic and Molaison, 2008). This acts as an impediment to rebuilding.*	*Greater New Orleans regional economy devastated, with negative impacts for inter-connected local economies including St Bernard's parish.* *Slow recovery of utilities and road repairs in the communities slowing down the propensity of people to return to the neighborhoods.*	*The communities remain dependent upon Murphy Oil, the US Army Corps of Engineers, local levee boards and FEMA.*

		• *treasured possessions lost causing distress* • *enormous disruption to families* • *long- drawn-out law suit causing distress and loss of time.* *(Sullivan et al,. 2009).*			

Table IV: Resources employed by Murphy Oil Corporation in adaptation and response/coping processes: chemical spillage caused by flooding in Chalmete and Meraux following hurricane Katrina

Resources / Stages of the disaster cycle	**Forms of Natural Capital**	**Forms of Economic Capital**	**Forms of Human Capital**	**Forms of Social Capital**	**Forms of Physical Capital**	**Extraordinary forms of post-disaster capital**	**Spatial scales / levels appealed to by the Actor**	**Temporal scales/ range of tapped resources**
Pre-disaster adaptation	*Exploitation of flat floodplain land (former coastal marshland) and proximity to river channel (for product unloading/ loading and transport purposes) to establish an oil storage tank farm and refinery in an area of the*	*Oil company financial resources employed to facilitate safety management and physical safety measure.* *Insurance cover to transfer risks (1).*	*Safety management resources employed in response to federal EPA regulatory regime for oil refinery/chemical safety (e.g. risk assessments, audits, inspections, remedial actions).*		*Earthen berms constructed around each oil tank in the tank farm to contain spillages.* *Taking advantage of levees for flood protection – levees provided by US Army Corps of Engineers.*	*None observed.*	*As a multi-national corporation Murphy had global resources potentially available but data are inadequate to identify whether they were employed.*	*None observed.*

	Gulf of Mexico rich in oil reserves.							
Post-disaster response		*$58m revenue spent by Murphy on its voluntary remediation program.* *A further $278m revenue allocated by Murphy for voluntary settlements, compulsory compensation, property buy-outs and remediation.* *Murphy also instructed to pay for all costs of litigation.* *FEMA (Federal Emergency Management Agency) paid for cost of demolishing homes.*	*Knowledge residing in the US Environmental Protection Agency(EPA) was called upon to assist with the clean up.* *Requested assistance from the US Environmental Protection Agency (EPA) and the US Coast Guard to deal with the oil spillage. These agencies decided to divide responsibility for this technical assistance and provided it. The EPA's Response and Prevention Branch took responsibility for overseeing the clean up and environmental monitoring and data recording.* *Emergency workforce of contractors paid for by Murphy employed to clean up the oil spillage and remove debris. Residential areas and streets sanded.* *Oversight also provided by Louisiana Department of Environmental Quality.* *Health risks and public advice addressed by the Agency for Toxic Substances and Disease Registry.* *Environmental sampling scheme established to measure and monitor soil and property contamination levels.* *Training for sampling teams organized by Murphy.* *Visual oiled-property surveys using contractors.* *Murphy seeks to limit its liability and agrees to pay $83m in voluntary settlements with property owners.* *Murphy loses legal case (US*	*Murphy interacted with local resident organisations to provide information after the disaster, but this was largely through public relations and legal lenses.* *The company employed legal resources to fight the legal action brought by residents and business owners in the community.*	*Murphy immediately employs its pumping equipment to recover oil from the site and canals: 72% of oil recovered.* *Boom deployed across canals to prevent escape of residual oil.* *Murphy returned to 'normal' oil refinery operations by mid-2006 leaving the affected community to recover more slowly.*	*Taking advantage of Government tax-bonds made available when US Congress created 'Gulf Opportunity Zone' after Katrina to encourage private businesses to make repairs and reconstruction.*	*Potentially national and multi-national because Murphy Oil Corporation is a multi-national business (2).* *Murphy appealed for assistance to the EPA and US Coast Guard at the regional level.*	*Flooding and oil spillage occurred in August 2005.* *Legal action won by residents in January 2007.* *Remediation, buy-out and compensation took place in 2007/8.*

			District Court, Patrick Joseph Turner et al. V. Murphy Oil USA, Inc., 2007) and is obliged as a result of legal action taken by residents to undertake a property buy-out program costing $55m for the worst contaminated properties. *Under the same legal action, the courts instruct Murphy to allocate a further $120m of financial compensation to property owners.* *Also Murphy instructed by courts to allocate a further $20m for remediation.*					

(1) It is not clear from the data available whether or not Murphy Oil Corporation transferred some or all of the risks associated with oil refinery operation to insurers. However, such insurance is available and used by oil companies and Murphy Oil Corporation is a major multi-national corporation that would be unlikely not to take advantage of such risk transfer opportunities.

(2) The data are insufficient to identify whether or not Murphy appealed to national or international levels within its own multi-national organisation to cope with the oil spillage and its implications. However, it is likely that for its legal, technical and public relations assistance it would have drawn on at least in-company regional and national resources. It may also have done so for financial resources.

Table V: Resources employed by the local parish population in adaptation and response/coping processes: flooding and subsequent chemical spillage in Chalmete and Meraux following hurricane Katrina

Resources / Stages of the disaster cycle	**Forms of Natural Capital**	**Forms of Economic Capital**	**Forms of Human Capital**	**Forms of Social Capital**	**Forms of Physical Capital**	**Extraordinary forms of post-disaster capital**	**Spatial scales / levels appealed to by the Actor**	**Temporal scales/ range of tapped resources**
Pre-disaster adaptation	*Residents and small businesses attracted to flat, former marshland area because*	*Purchase of hurricane and flood insurance by householders and small businesses. However not all possessed this insurance and in some cases insurance agents*	*Individual and household human psychological resources.* *General awareness of hurricane and flood risk but much of this risk perceived to be reduced by presence of flood levee –*	*Community, neighborhood, school and church groups provided support networks. Many residents had lived in the*	*Dependence upon flood surge levees built in the 1960s by the US Army Corps of Engineers.*	*None observed.*	*The local population relied upon a city-wide/sub-regional system of levees that*	*Long-standing social relationship within the communities which were a key feature of*

	of family histories of living and doing business there, affordability of homes, and in some cases employment in the oil refinery.	*had told those asking about purchasing insurance that it was not necessary.* *Some expenditure on strengthening homes and structures against wind damage.* *Negligible expenditure on measures to protect properties from flooding because of protection from flood levees.*	*population elected to live and work behind flood defenses believing it to be protected – adapting psychologically to the risk and taking comfort in numbers.* *General awareness of the risks associated with the proximity of an oil refinery and oil tank farm to a residential and small business neighbourhood. This awareness was translated into anxiety for at least some of the local population because of a recent fire in the refinery, drinking water contamination issues(from oil spillages) and because of general concerns about terrorism, - but, despite experiencing several evacuations because of fire and other incidents in the refinery, the population elected to live and work in the area relying upon the chemical safety regulatory regime of the USA - adapting psychologically to the risk and taking comfort in numbers.*	*community for many years enabling well developed social networks.*			*were designed to protect Greater New Orleans from flooding.*	*the social capital.*
Post-disaster response	*As above, but the attractiveness of the area was severely reduced by flood damage, dereliction and long term contaminat-ion concerns.*	*Initially, federal funded emergency response teams; then trailers funded by FEMA for many made homeless.* *Clean up of oil contamination funded by Murphy Oil Corporation. Demolitions funded by FEMA.* *Eventually financial compensation as a result of legal case brought by residents against Murphy Oil.* *Insurance payout resources for those who*	*Members of the local population had to draw deeply on their own mental, physical and emotional resources.* *Web resources and telephone help lines used to communicate with co-victims and to work through traumas.* *Volunteers, emergency aid workers, friends and family members all provided support: members of the local population varied in their ability to take advantage of these opportunities.*	*Legal systems used to prove negligence and to gain a rebalancing of vulnerability in the local population's direction.* *Volunteer help provided by church and other organizations.* *Family assistance to help some who were made homeless and had to leave the area.* *Major support*	*Levee repair work and eventual improvement of the standard of flood protection by US Army Corps of Engineers.*	*Volunteer and charitable assistance was very significant in post-disaster support and recovery.* *Federal aid to community was large but slow in being delivered.* *Class action (i.e. legal case) released large financial resources to compensate many residents.*	*Local and federal scale assistance.* *Families appealed to their families and friends for initial help but then to the federal government.* *Walk-in help centers used by many as volunteer help became available.*	*Post-disaster response is taking many years for this heavily damaged and traumatized community.*

		were insured. *Numerous State, Federal and NGO funding sources became available for the recovery effort.*		*required by health services.*			*The entire sub-regional levee system is being reconsidered and improved.*	

Table V: Internal rebalancing of vulnerability facets by Murphy Oil Corporation

Rebalancing the facets / Stages of the disaster cycle	***Physical***	***Social***	***Economic***	***Systemic***	***Institutional***
Pre-disaster adaptation	***Reduction*** *By locating in a protected floodplain; protecting against high wind damage; purchasing hurricane/flood insurance; and investing in oil contamination berms for tank farm).*	***Reduction*** *As for physical – physical protection of employees.*	***Reduction*** *Company's assets located in protected floodplain, also covered by insurance. Investment in oil contamination berms for tank farm.* *Potential consequential losses owing to oil production stoppage protected to some extent by flood protection.*	***Reduction*** *Murphy Oil Corporation is a multi-national oil company which is able to spread its weather-related risks amongst the regions of the world in which it operates.*	***Reduction for Murphy Oil Corporation*** *As for physical, social, economic and systemic.* ***Reduction for FEMA and US Army Corps of Engineers*** *adopted policies and procedures which they hope would be successful in adapting them to the risks associated with hurricanes and storm surge.*
Post-disaster response	***Further reduction*** *By taking advantage of US Army Corps of Engineers' plan to upgrade from 2011 the standard of protection to the Chalmete and Meraux communities.*	***Further reduction*** *As for physical – higher standard of physical protection of employees.*	***Increase in the short term, but decrease in the medium term*** *Murphy Oil Corporation found negligent in class action and forced to pay massive financial compensation to homeowners and businesses in Chalmete and Meraux, as well as to cover some of the cost of oil contamination clean up.* *Oil production stoppage for about six months – loss of revenue and*	***Further reduction*** *Vulnerability to losses cushioned by US Congress financial incentives for recovery and to remain located in US Gulf of Mexico.*	***For Murphy Oil Corporation -increase in short term, but decrease in medium term*** *As for economic and systemic* ***Increase in vulnerability for FEMA and US Army Corps of Engineers.***

			depressed profit. *However, in the medium term the company's assets will be protected to a higher standard of protection from flood surge after 2011, and this also reduces vulnerability to oil production stoppages caused by natural disasters.*		*FEMA became a vulnerable institution in the aftermath of Katrina because its disaster response was too little, too late for many and was very heavily criticised. The US Army Corps of Engineers has also received significant criticism for its failed flood protection policies in New Orleans (Southwell and von Winterfeldt, 2008).*

Table VI: Internal rebalancing of vulnerability facets by local population of Chalmete and Meraux

Rebalancing the facets / Stages of the disaster cycle	***Physical***	***Social***	***Economic***	***Systemic***	***Institutional***
Pre-disaster adaptation	***Reduction*** *By locating in a protected floodplain, homeowners and local business owners reduced their vulnerability to flood loss to property.* *However, those that moved into the community placed themselves close to the oil refinery accepting a bundle of risks (e.g. fire, explosion, terrorism) and a vulnerability which would not be present in most other locations.*	***Reduction*** *By locating in a protected floodplain, homeowners and local business owners reduced their vulnerability to loss of life and injury in a flood.* *However, those that moved into the community placed themselves close to the oil refinery accepting a risk to life and a risk of severe disruption to their lives - a vulnerability which would not be present in most other locations.*	***Reduction by some, but not by others*** *Some homeowners and small local businesses purchased hurricane and flood surge insurance. Some of these were not covered to the degree that they believed to be the case. Others had not purchased disaster insurance, and in some cases they were advised that they did not require it.*	***Reduction*** *The development and accumulation of social capital in this fairly tight-knit community afforded a major potential adaptation.*	***Not applicable.***
Post-disaster response	***Reduction*** *The physical vulnerability of the homes and businesses in the community will be reduced, but*	***The impact is complex*** ***Increase for some*** *For more than 150 people who lost their lives, post-disaster response*	***The impact is complex*** ***No change or increase for some*** *As a result of the dynamics of the*	***Increase*** *The community suffered a major loss of social capital.* *Major loss in sense of security*	***Not applicable.***

	not eliminated, when the promised higher standard of flood protection is provided for the area in 2011. *Homes and business premises have been demolished, repaired or replaced, although the number of buildings in the community is significantly less than before the disaster.*	*vulnerability reduction was not an option. There is bound to be a lasting negative impact of this on the families and friends of those lost.* ***Significant increase for many but possibly no change for others*** *The loss of community, the loss of familiar social groupings and support networks, the 'thinner' local population, and the consequent reduction in social capital opportunities has almost certainly lead to a significant increase in vulnerability for many, though probably not all.* ***Reduction*** *For most of those who have migrated permanently from the community, and re-made their lives elsewhere.*	*insurance industry: it is not now possible to purchase disaster insurance from private insurers in post-disaster Chalmete and Meraux because they have withdrawn from the market. Insurance can be purchased from a State body but at much higher prices, deterring some.* ***Status quo (no change) in economic vulnerability*** *-* *produced by compensation payments as a result of the legal action.* *£55m paid to property owners to buy-out and remediate properties in the buy-out zone* *$120m paid to all property owners as compensation.* *£83m paid to those who opted for the voluntary resettlement programme.*	*and major increase in stress and uncertainty in people's lives leading to ill-health effects.*	

Table VII: Internal redistribution of vulnerability to disaster stages and to new hazards by a) local population and b) oil company

Redistribution in time and to other hazards / **Stages of the disaster cycle**	***Vulnerability in pre-disaster terms***	***Vulnerability during the emergency period***	***Vulnerability during recovery / reconstruction***	***Vulnerability to the next event and/or new hazards***
Pre-disaster adaptation	***Social*** *Reduction for (a) owing to temporal build up of social capital and levee protection for community population.* ***Physical*** *Reduction: for (a) and (b) owing to levee protection and constructional measures against*	***Social*** *Reduction for (a) owing to hurricane surge warning system and pre-disaster evacuation plan. Also reduction for employees of (b) owing to warning system.* ***Physical*** *Reduction: for (a) and (b) owing to measures that could be taken on receipt*	***Social*** *No change – hardly any adaptive measures taken in advance of disaster, but innovative potential exists (e.g. for volunteer involvement and emergency support systems funded by NGOs and governmental agencies).* ***Physical*** *Some reduction: owing to disaster*	***Social*** *No reduction of vulnerability to hurricane surge or to the oil spillage hazard.* ***Physical*** *No change in vulnerability.* ***Economic*** *No change in vulnerability.* ***Systemic***

	high wind damage. ***Economic*** *Reduction: for (a) and (b) owing to levee protection and insurance.* ***Systemic*** *Reduction: for (a) and (b) owing to levee protection, insurance and social capital accumulation.* ***Institutional*** *Reduction: for (a) and (b) owing to levee protection, regulatory measures taken against oil spillages and risk spreading by multi-national oil company.*	*of warning.* *Oil refinery mitigation plans existed and were filed with local government, but based on heavy rain flood event and not flood surge.* ***Economic*** *Reduction: for (a) and (b) owing to measures that could be taken on receipt of warning.* ***Systemic*** *Reduction: for (b) owing to – as above, plus the potential for risk spreading owing to the regional, national and international distribution of the oil industry.* ***Institutional*** *Potential reduction: through the existence of and preparations made by the Federal Emergency Planning Agency (FEMA), and state- and city-wide emergency planning measures.*	*emergency accommodation plans by FEMA.* ***Economic*** *Increase: owing to loss of employees and customers affecting small local businesses* *Some reduction: owing to FEMA's and NGO pre-disaster planning for economic and financial assistance to communities struck by disaster.* ***Systemic*** *Some reduction: owing to above.* ***Institutional*** *Some reduction: owing to above.*	*No change in vulnerability.* ***Institutional*** *No change in vulnerability.*
Post-disaster response	***Social*** *In the short to medium term the community is more vulnerable because some died and many have not returned – and the social capital has been damaged in a major way.* ***Physical*** *Reduction in vulnerability. The buildings are being reinstated and refurbished but not to a higher level of resilience against hurricane and flood surge. The levees are being constructed to a higher standard of protection.* ***Economic*** *In the short term the community has been more vulnerable, but in the medium term financial*	***Social*** *The warning systems are being improved over time allowing vulnerability to be further reduced.* ***Physical*** *The levees should be stronger in future reducing vulnerability.* ***Economic*** *Probably no change although learning from the disaster may introduce new economic contingency planning measures.* ***Systemic*** *As above.* ***Institutional*** *Probably a reduction in vulnerability stemming from the heavy criticism of*	***Social*** *Not much change observed.* ***Physical*** *No change observed.* ***Economic*** *No change observed.* ***Systemic*** *Possibly some reduction owing to learning process.* ***Institutional*** *As above.*	***Social*** *No change observed – but there are a range of hazards present.* ***Physical*** *As above.* ***Economic*** *As above.* ***Systemic*** *As above.* ***Institutional*** *Possibly a reduction in vulnerability owing to criticism and to failure or oil industry spillage/leakage regulatory systems.*

	compensation is likely to lead to a no change/status quo for most. ***Systemic*** *No change or status quo is being reached.* ***Institutional*** *Learning process of the disaster may lead to reduced institutional vulnerability.*	*the federal and city emergency response and the post disaster inquiries which have taken place allowing a process of institutional learning.*		

Table VIII: Transfers of different facets of vulnerability to other actors by Murphy Oil Corporation over time

Black text gives the context. Transfers are identified in red. Reverse transfers to local population are shown in blue.

Transferring vulnerability to other actors / ***Stages of the disaster cycle***	***Social actors*** ***i.e. the local population of Chalmete and Meraux***	***Economic actors*** ***i.e. the wider multi-national company, shareholders, insurance companies; Federal Government***	***Institutional actors*** ***i.e. US Army Corps of Engineers; US Coastguard; FEMA; State Emergency Response organisations, NGOs.***	***Territorial systems*** ***i.e. neighbouring communities and States; other regions in which Murphy operates.***
Pre-disaster adaptation	***Social*** *The economic advantage of locating on oil refinery in the community led Murphy to create a vulnerability to explosion, fire and oil leakage and spillage/ contamination through its co-location with the communities and through the risks and incidents which arose prior to Katrina.* *It also created a vulnerability by co-locating in the flood plain, and in a hurricane flood surge zone.* ***Physical*** *As above.* ***Economic***	***Social*** *Murphy created a major economic vulnerability with the potential to threaten the economic viability of the local community. No social adaptations were made to offset this vulnerability.* ***Physical*** *As above, except regulatory measures to protect oil leakage from fixed oil tanks by using berms was employed to reduce vulnerability.* ***Economic*** ***As below*** ***Systemic*** *Murphy could draw upon its multi-*	***Social*** *These actors provided a disaster emergency response capability required because of hurricane, flood and related na-tech risks but there is no significant transfer from Murphy involved here.* ***Physical*** *As above although the risks of fire, explosion etc. posed by the oil refineries placed additional demands upon local institutions such as fire fighting ones.* ***Economic*** *As above.* ***Systemic*** *None*	***Social*** *Neighbouring communities throughout Greater New Orleans presented with very similar flood surge threats although not all faced the oil contamination threat faced by Chalmete and Meraux. Adaptations mainly structural engineering or levee systems.* ***Physical*** *As above.* ***Economic*** *As above.* ***Systemic*** *As above.*

	As above although the impact was mediated by the provision of oil refinery employment for members of the community. *Murphy possessed disaster and accident insurance but not for the community. So it placed the onus on the community to recover damages (at least until after the court case).* *Some community members possessed disaster insurance.* ***Systemic*** *None.* ***Institutional*** *None.*	*national financial security and assets, potentially transferring some of its locational vulnerabilities to the wider corporation and to stakeholders including shareholders.* ***Institutional*** *Murphy and other oil companies have the support (political and therefore also economic) of the State and Federal Governments.*	***Institutional*** *None*	***Institutional*** *As above.*
Short term post-disaster response (i.e. up to 18 months after the disaster)	***Social*** *Murphy transferred a substantial part of its own institutional vulnerability to the local population by (a) not ensuring that all of the oil tanks were secured and that oil leakage and widespread oil contamination of homes and businesses did not occur, and (b) by not having disaster mitigation plans which addressed hurricane storm surge risks.* *The local population experienced a major increase in their vulnerability as a consequence.* *Murphy transferred its institutional vulnerability into a social vulnerability for the community in that a major oil contamination incident severely blighted the lives of members of the community.* *Responsibility for dealing with aftermath transferred to families of victims* ***Physical***	***Social*** *None* ***Physical*** *Murphy sought to reduce vulnerability of properties by its emergency oil clean up operation.* ***Economic*** *Murphy transferred its physical vulnerability into an economic one for the community in that a major oil contamination incident severely blighted the value of properties in the community.* *Murphy transferred some costs of clean up and environmental regulatory actions to the US Coast Guard, FEMA and to State agencies who paid for these responses. Ultimately the costs were transferred to the US taxpayer.* *Insured property owners transferred costs to insurance companies. However, many insurance companies subsequently withdrew from selling insurance in the communities thereby transferring back*	***Social*** *Responsibility for dealing with the social aftermath significantly transferred to Federal and State emergency response organisations and NGOs (helped by the flood coinciding with the soil contamination).* ***.Physical*** *As above, although the responsibility was partly shared by Murphy.* ***Economic*** *As above.* ***Systemic*** *None* ***Institutional*** ***None***	***Social*** *Volunteers from many parts of the USA involved in helping reinstate the community. Victims evacuated to neighbouring communities, many not returning and migrating to other locations in Louisiana and to other States.* ***Physical*** *Shelter and accommodation found by victims in neighbouring locations in Louisiana and in other States.* ***Economic*** *Funds from the national and State level drawn into coping with economic impacts. This is a transfer of costs to US taxpayers.* ***Systemic*** *Many States linked in a variety of ways to the post-disaster response e.g. providing repair contractors; providing volunteers, providing equipment etc. and affected by oil shortages and price rises.*

	Homes and business buildings were either destroyed by the flooding (not a transfer from Murphy) or were contaminated by oil to different degrees (a transfer from Murphy). ***Economic*** *Home and business owners who suffered oil contamination experienced a major loss in the market value of their properties, severe damage (some uninsured), and extra costs (e.g. of temporary accommodation, loss of time etc.).* ***Systemic*** *Major increase in vulnerability owing to indirect and less tangible impacts of stress, anxiety, consequent illnesses, depression etc. affecting families and community groupings.* ***Institutional*** *Social capital of the community was heavily damaged by the flood surge (not a transfer from Murphy) and to some extent by the oil contamination (a transfer from Murphy).*	*the vulnerability to property owners in the future.* ***Systemic*** *Economic vulnerabilities were felt throughout the US oil production and consumption system as well as globally as Murphy was part of a much larger oil industry disrupted severely by Katrina.* ***Institutional*** *Major transfer: Federal and State agencies had substantial financial costs transferred to them by Murphy as a consequence of the oil contamination incident.*		***Institutional*** *Regional level organizations of federal organizations involved in the immediate post-disaster emergency response.*
Medium-term post-disaster response (i.e. more than 18 months after the disaster)	***Social*** *Reducing vulnerability because of reverse transfer: the major increase in social vulnerability was to some extent reduced as an indirect effect of the financial compensation paid by Murphy to community members whose properties were contaminated by oil – this must have alleviated anxiety and stress, although the legal action would have been stressful.* ***Physical*** *No change: the reinstatement of homes and business properties (with the demolition and buy-out of the worst affected) is gradually leading to*	***Social*** *Gradually reducing vulnerability: as clean up progresses.* ***Physical*** *No change.* ***Economic*** *Reduced because of reverse transfer: financial compensation paid to homeowners and business people whose properties were contaminated, reducing their economic burdens and vulnerabilities.* ***Systemic*** *None. Shock to regional and national*	*As above for all vulnerability types, but vulnerability gradually reducing to pre-Katrina levels or possibly below this.*	*As above for all vulnerability types, but vulnerability gradually reducing to pre-Katrina levels or possibly below this.*

	the pre-disaster, status quo in terms of physical vulnerability. ***Economic*** *Reduced because of reverse transfer: financial compensation paid to homeowners and business people whose properties were contaminated, reducing their economic burdens and vulnerabilities.* ***Systemic*** *Reverse transfer: Gradually reducing: as a result of lessened anxieties following financial compensation.* ***Institutional*** *Reducing from a very high level of vulnerability: the community is gradually recovering and regaining members, with the social capital building up once again but still a long way to go.*	*economies now over.* ***Institutional*** *Reducing impact on Federal and State budgets.*		