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Inductive Modelling of Vulnerable Sustainability Systems

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Abstract

Within the context of globalisation, managing territorial resources means overcoming the following problems: difficulty in implementing integrated management processes at various organisation levels; conflicting uses; unadapted decision systems, assymetric information and uneven operative processes in each dimension of sustainable development. To illustrate and overpass those difficulties in a territorial level, we propose to introduce an analogical induction-model to describe both vulnerability situations and associated resilience procedures. The construction of this model is founded on a truly integrated approach, combining the economic, social-cultural, and ecological aspects of territorial vulnerability. Constituted by three passive components as potential energy, kinetic energy, and energy dissipation, this approach assumes that economics are a social extension of a environmental energy system. So we claim that social and ecological pillars could be defined as subsystems of a global open inductive sustainability system which considers feedbacks as evolution sources. An applicative illustration of this model will then be presented, through a case study describing 2012's American severe drought event.

Keywords

Vulnerability, Resilience, Inductive Model, Sustainable Development, Socio-Ecological Transition

1. Introduction: About Resilience

Along with the elaboration of sustainable policy sequences, new concepts and paradigms such as resilience have emerged. Resilience (from the Latin etymology “resilire”, to rebound) is literally the act or action of springing back. The notion of resilience has then been elaborated in different domains, as in child psychology and psychiatry, where Engle *et al.* [1] refer to living and developing successfully when facing adversity; in ecology,

Holling [2] refers to moving from a stable domain to one under the influence of disturbances; in business, Hamel *et al.* [3] refer to the capacity to reinvent a business model before circumstances force it to; in industrial safety, Hollnagel *et al.* [4] refer to anticipating risk and making changes before the occurrence of damage.

Resilience research was pioneered in the 1980s by psychologists including Werner, Garmezy, Rutter, Cyrulnik [5] and others through focusing on personal adaptive capacities to be mobilized under a range of adverse conditions. Within this context, “resilience” referred to a dynamic process—the reactive protective factors—encompassing positive adaptations despite exposure to significant adversity.

The resilience of an ecological system relates to the functioning of the system as a whole rather than the stability of its individual component population (Holling *et al.* [6]). These important features of ecological resilience have been meaningfully adapted to social systems.

Resilience theory also claims that entropy constitutes a measure of adaptive systems (Bailey [7]) defining to what constraint quality and level the environmental system is able of self-repairing, through multidimensional sustainability converging. Resilience theory states that perturbed systems soon returns to a stable equilibrium, sometimes different from the original one. Thus, social systems resilience traduces the capacity of human societies to face conjectural stress after experiencing adverse events such as fire, flood, sudden economic downturn or drought by anticipating change with adapted policies and programs (Munasinghe [8], Costanza [9]).

2. Resilience and Development Capitals

In other words, community resilience can be understood as the ability and capacity to deal with and adapt to changing conditions and continue to develop. For this to happen, governments, private industries and organisations, formal and informal structures, communities and individuals all have a role to play in the process, by identifying, developing and retaining the essential ingredients of resilience, which can be expressed through sustainable development capitals.

2.1. Social-Cultural, Economical and Ecological Capitals

Pierre Bourdieu [10] defines Social Capital as the sum of resources incorporating the knowledge, skills and health status of the population, including attachment to and trust in social groups/associations and cultural knowledge, education, training, physical and mental health status, values, and personal characteristics, as well as co-operation networks, shared values and understanding (Coleman [11]); In that acceptance, social capital implies norms and values to facilitate exchanges, reduce information and transaction cost, thus encouraging citizenship responsibility, and, therefore, the collective management of resources (Fukuyama [12]).

Social capital is therefore treated as a mediating variable, shaped by public and private institutions, which strategy combination has important impacts on development outcomes. It can also be a power trade for cooperative action, through policies participation or collaborative intelligence (Putnam [13]).

Economical capital covers money, machinery and infrastructure providing physical assets of businesses and households, as well as public or community physical infrastructures, or produced goods and services created by converting flows of services from stocks of community wellbeing “outputs”. Moreover, economical capital is sometimes considered in a separate way from financial capital, which refers to the funds that are available to individuals and groups in a community. This form of capital can generate a flow of income to support the holder’s immediate wellbeing, but it can also be converted into some other form of capital, to contribute to community wellbeing.

Ecological capital recovers goods and services items such as exploitation or transformation of natural resources, specific land-use and settlement patterns, biodiversity management, nature valuation, landscape preservation, sustainable farming and food production. Hence, the ecological stock represents objectified and accumulated labor (Bourdieu, [14]), as context-related knowledge describes the interrelations between natural resources and amenity production through effective adjustments in land-use (Swagemakers, [15]). As neo-classical economics stated a separate organization from environment and a total freedom from biophysical constraints, economical think-tank interested with natural resources and environment introduced ecological capital notion to refer to the limited natural resources stocks, with considering economy as an open-growing totally dependent subsystem of a closed, non-growing finite ecosphere system, as illustrated **Figure 1**. Thus, ecological capital dimensioning introduce a highly-ordered dynamic system governed by the second law of thermodynamics, its entropy being directly in- and out-putting to ecosphere energy/matter equilibrium (Rees [16]).

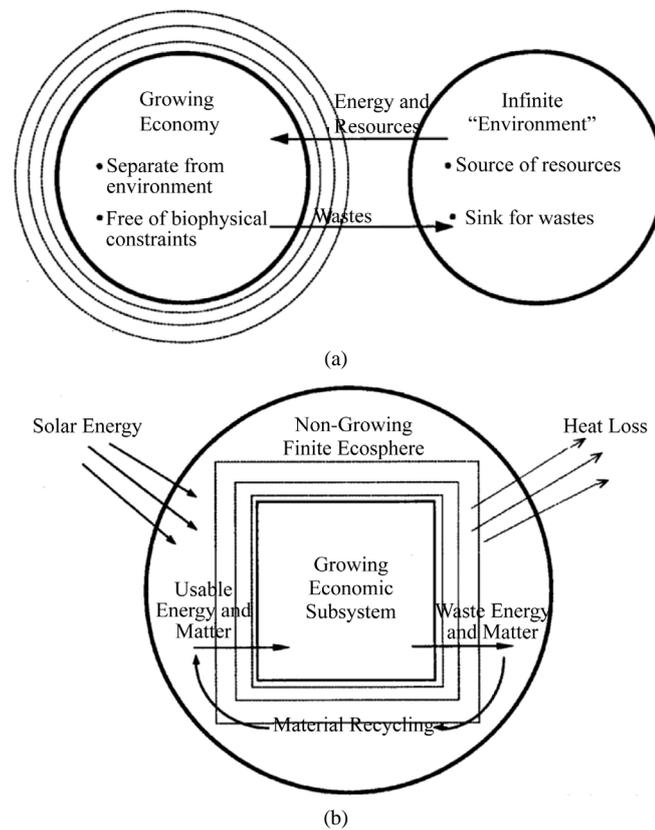


Figure 1. From expansionist (neo-classical economics) to “ecological” paradigm (Rees [16]).

From this point of view, human society remains dependent of the ecosphere for both usable energy/matter production and waste assimilation.

2.2. From Stocks to Flux

Those three kinds of capital, when combined, generate a wide range of “outputs”, or wellbeing attributes, that are important in terms of community valuation. As a complex combination between economic, environmental and social life values, outputs that people may need or seek in order to maintain their wellbeing involve complex forms of joined eco/socio/environmental inputs. Therefore, community can be considered as a complex system provided by economic, social-cultural, and environmental goods and services. Societal amenities can thus be considered as a conversion result from stocks of various forms of capital (“inputs”) into flows of services or amenities (“outputs”).

Hicks [17] stated that maintenance of the wellbeing of a community was a function of income flow maintenance from a stock of capital. With defining the stocks of a community’s capital, one can generate enough flows for community wellbeing to provide the rise (or fall) in a community’s wellbeing by increasing (or decreasing) its stocks of capital. Therefore, community resilience increase is an effect of its capability to extent its available capitals in the three (social/economical/environmental) dimensions of sustainable development, acting as a buffer against forces that test a community’s ability to cope with change.

To enable good decision-making practices, sustainability modeling should therefore evaluate the territorial communities capitals circulation structure, through stock to flow transformation characterization during production/ consumption/ exchange processes between economy, society and environment.

3. Towards Sustainability Convergence at Territorial Levels

A better understanding of perspectives for territorial development could be provided through cross-analysis be-

tween social, economical and ecological dimensions at different scales: globalization environmental dumping (Spangenberg & Bonniot [18]), socio-environmental assessment (Blake [19]), or eco-efficiency viability development (Martens & Rotmans [20]).

3.1. From Economics to Environment: The Econological, Ecosocial and Socioecological Sustainability Pillar Combinations

The “econological” paradigmatic change involves a technical cost-minimization strategy for industry and an alternative to laborsaving investment—a form of “ecological rationalization” which will lead simultaneously to greater ecological and economic efficiency. Therefore, when talking about eco-environmental objectives convergence, industrial societies usually refers to broadly framed “environmental politic” strategies commonly found in industrial countries. Its underlying strategies are remedial (compensation and environmental restoration), preventive (technical pollution control) or anticipatory (environmentally friendly technical innovation). (Janicke [21]). Hajer [22] considers economistic—framing environmental problems in monetary terms, portraying eco-environmental protection as a “win/win” game and following an utilitarian logic. At the core of sustainable eco-environmental development, objectives convergence usually follows the idea that pollution prevention pays. In this way, it is “essentially an efficiency-oriented approach to the environment” (Hajer [22]), so that economic growth and environmental protection action can be reconciled. For Weale [23], sustainable development eco-environmental objectives convergence involves a new belief system that articulates and organizes ideas of ecological emancipation. Thus, environmental protection as a condition of long-term economic development implies the important role of belief systems in public policy organization for eco-environmental problem solving.

To enable social links facilitating the sustainable development, people need to feel sufficient impact in the social space to act. Analogy with Fukuyama’s “Circle of truth” (Fukuyama [12]) refers to the area in an individual’s social space within which he feels “adapted” to interact socially. Therefore, “social capital” constitutes a quantifiable component of meso-level economic activity, generally declined as information, trust, and norms of reciprocity inhering for mutually beneficial collective action (Raskin *et al.* [24]). Economists, sociologists and political scientists working within the field of the so-called “new economic sociology” have thus defined social capital as a tool encompassing the norms and networks facilitating collective action for mutual benefit.

Increasing social capacitance of the inhabitants within collaborative experience facilitate the access to the main “social body”, civil society, with developing new ecological and meanings of social life. Growing individual stocks of socio-ecological capital provided by collaborative experiment such as Miller’s Park initiative described in (Woloszyn-Faburel [25]) may act as a buffer against forces that will occur when inhabitants are faced to common socialized environments. Thus, this contributes to the renewal of the resilience potential, passing from resistance (“Input” social capital) to adaptation (social to eco-social capital circulation) and transformation (inductive effect of stock to flow conversion), as described in the “E.S.O. model” presented next section.

3.2. Interlinking the Sustainability Dimensions

If we represent the three interlinked sustainability dimensions of territorial vulnerability (socioeconomical, ecological, socioecological), their dynamic interdependencies describe a triangular trade-off schematic (see following **Figure 2**): one can see on the first side that “Econological vulnerability” enlightens the use of resources that could become scarce as a consequence of hazards occurrences. Induced variation of the vulnerability system, for example, econological vulnerability, illustrates failures of the global transition towards sustainable systems through environmental degradation. This last, mainly due to the materialist-consumerist paradigm, *i.e.* economic growth, is mainly combined with the diminution of social-cultural capital.

On a complementary side, “Socio-ecological vulnerability” clearly refers to the fact that natural resources are overused to ensure a basic standard of living, thus placing a great deal of pressure on the ecological capital. Moreover, territorial development would therefore not only depend on vital supplies, but also on education, income levels and amenities access. At the last side of the sustainability trade-off interaction triangle, “Socioeconomic vulnerability” breaking point can be detected where the cost of the system stability exceeds both the value of the property threatened and the financial means of the territorial decision-making process. So, vulnerability studies should simultaneously imply economical trading functions, human societies ideals and ecological systems parameters, through their corresponding capitals such as socioeconomic conditions, lifestyle preferences and consumption behavior. Thus, policy rules should be underlined by biodiversity and cultural assets dimensions.

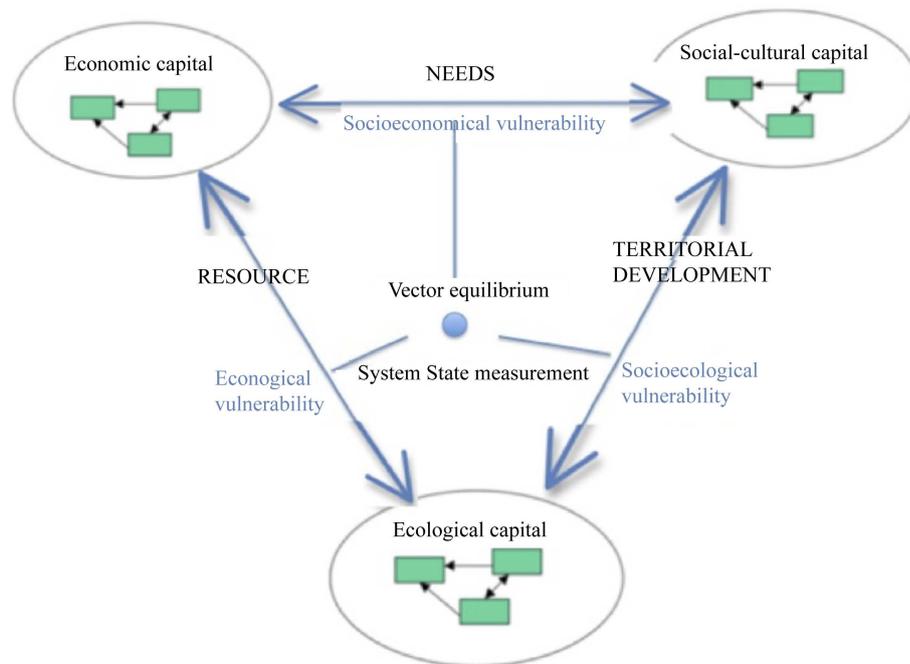


Figure 2. Articulation and convergences between sustainable development capitals.

While adopting a holistic systemic viewpoint, this transitional conception of territorial development may be evaluated by its adaptive capacity to answer to the pressure of major effects of the changes in its environment as well as inequalities access to amenities (Faburel [26]). Thus, taking sustainability dimensions interactions into account should help to identify the benefits of cooperative structures and decision-making at local levels, and therefore to measure the consequent benefits of policy rules on the socio-eco-environmental global system.

In this prospect, corresponding decision and regulation instruments have also to converge, aiming to create adaptive conditions through sustainable development socio-political expertise. Here, socio-political dimension of resilience, implying not only public policy, but also other stakeholder decisions and actions, has to ensure the capacity to restore the trust of populations. Territorial intelligence of vulnerability systems will therefore depends on local capacities to empower people in order to facilitate their involvement in decision-making process linked to socio-ecological transition goals. To achieve it, we introduce an analogical induction-model to describe both vulnerability situations and associated resilience procedures, inspired from a well-known late 80's model of socio-economic crack-up, known as "Silent Weapons for Quiet Wars", which was uncovered quite by accident on July 7, 1986 when an employee of Boeing Aircraft Co. purchased a surplus IBM copier for scrap parts at a sale (Cooper [27]).

4. The E.S.O. Transition Paradigmatic Model

"Silent Weapons for Quiet Wars" technology is an outgrowth of a simple idea, succinctly expressed and effectively applied by the quoted Mr. Mayer Amschel Rothschild. The latter discovered the missing passive component of economic theory known as "economic inductance": currency or deposit loan accounts, which has the required appearance of power that could be used to induce people into surrendering their real wealth in exchange for a promise of greater wealth. This model, also named "E-model", exposes economics as a social extension of natural energy systems. It is constituted by three passive components, potential energy, energy dissipation and kinetic energy, thus allowing economical data to be treated as a thermodynamical system. To extend this model to social and ecological sustainability pillars, we propose to built an extended E (Economic)-S (Social)-O (Organic) open model.

4.1. General Energy Concepts: Towards a Generalized Social Energy Model

In the science of physical mechanics, potential energy is associated with a physical property called elasticity or

stiffness, and can be represented by a stretched spring. In electronic science, potential energy is stored in a capacitor instead of a spring. This property is called capacitance. Second passive component, energy dissipation, is associated with a physical property called friction or resistance, thus converting energy into heat. Third component of the system, kinetic energy, is associated with a physical property called inertia or mass, and can be represented by a mass or a flywheel in motion. In electronic science, kinetic energy is stored in an inductor (in a magnetic field), so that its property is called inductance. Within study of energy systems, the two first elementary concepts, potential energy and energy dissipation constitute the physical analogical counterparts of stock and flow generation into development process. Moreover, stocks of a community's capital ability to generate flows of community wellbeing are therefore modeled as an induction process of the community system, which physical counterpart corresponds to the inertial concept of energy systems, kinetic energy. Within E.S.O. paradigmatic model, those physical "passive components" of the corresponding mechanical/electronic systems have been traduced within the global sustainability system, as seen **Figure 3**.

By converting capital stocks into service flows in the three dimensions of sustainable development, stocks are understood as constitutive of the "capacitance" property of the system, as "flows" constitute its conductance, leading to capital stocks growing or declining. This system evolution describes the "inductive" effect of the (stock/flow) conversion process. As a consequence, analogies of potential, dissipative and kinetic energy concepts within the three pillars of sustainable development leads us to define the three dynamical notions of a general theory of social-eco-environmental entropy, also taking part of the "generalized social energy": capacitance, conductance and inductance (Dumas-Woloszyn [28]). Thus, sustainable co-evolution of environmentalized systems answer to those complementary processes, as illustrated **Figure 4**.

E-Model Economic inductance can be understood as an analogy with an electrical inductor: this last has an electric current as its primary phenomenon and a magnetic field as its secondary phenomenon. E-model describes an economic inductor as a complex flow driving, constituted by economic value as its primary phenomenon and population behavior as its secondary field phenomenon of inertia. Social Inductance (S-Model) considers social implying cooperation action as primary phenomenon and environmental integration process as secondary field phenomenon. Last but not least, Ecologic/Organic Inductance (O-Model) implies ecological management as primary phenomenon and ecosystemic interactions benefits/losses balance as secondary inertial field phenomenon. A further description of those passive components is given following **Table 1**.

Thus, this analogy identifies the "stock" as the capacitive property of the system to maintain or develop its capital, the "flow" as the conductance processes of capital production, and the "benefit" (or loss) of the system driving as the inductance effect of stock to flow capital recovering. During the "flowing" motions, inductance supplies to both capacitance and conductance, with taking into account the systems transformation potential

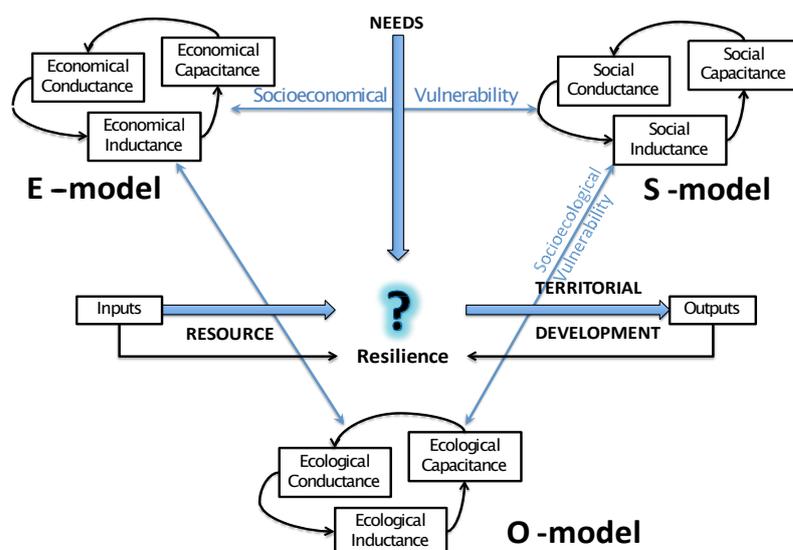


Figure 3. E.S.O. open-analogical model of sustainability and territorial in- and outputs.

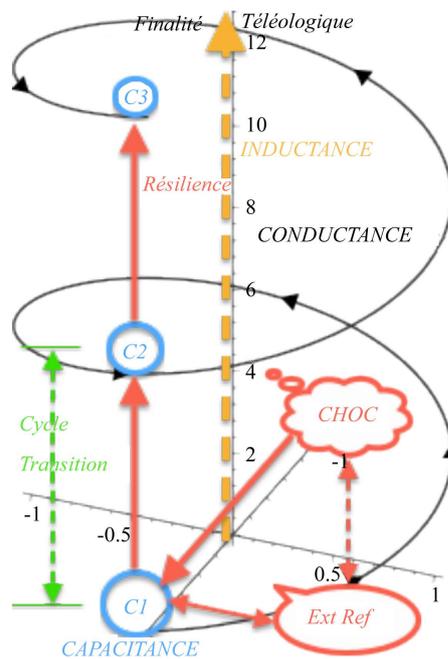


Figure 4. Open-analogical model of inductance behavior (Dumas-Woloszyn [28]).

Table 1. Combined capitals between environmental, economic and social values.

Property (Entropy class)	Economical (Model E)	Social (Model S)	Ecological-Organic (Model O)
Capacitance (Potential)	Capital (stocks) Money-Infrastructures Skills-Trust	Cultures, Social capital (actors & networks...)	Ecological capital Bio-hydro-litho-atmo-spheres
Conductance (Dissipative)	Flux (Goods) Services production Financial outcomes	Networking Cultural action Cooperation	Eco-actions Ecologic management Nature valuation
Inductance (Kynetical)	Resultance (Added/Lost Value...) Long-term benefits	Integration-differentiation Social wellbeing	Ecosystemic interactions Fertilization-desertification Amenity outcomes

through their temporal activities. This paradigmatic change of the process leads us to consider a thermodynamic approach of open-living systems, instead of mechanical-closed systems: stability key of those lasts closed systems, retroaction, is here considered as the open-subsystems evolution source.

4.2. Inductive Effects: A Recent Crisis Case Study, Historical drought in United States?

When a community’s capital stock is growing, its capacity to generate flows of goods and services will also grow, and thus enables the community’s ability to improve its wellbeing. So we can consider induction of the socio-eco-environmental system as the community’s capital stocks capacity to generate flows of community wellbeing. In case of dysfunction between this capacitance level and related conductance process, inductance should exceed capacitance, and a leading power factor will be produced, driving community to uncontrolled economic/social flows and harmonic problems. This equilibrium disruption will then cause an overflow of the dissipative system, driving the system to crisis. As a recent example, such an induced effect generated the 2007’s crisis, which can be interpreted as excessive financial flows resulting from American subprimes system, thus leading to a “savage” inductance process, implying financial crash and worldwide social crisis. Harmonic problems of eco/socio/environmental interactions can then be pointed out when the dissipative system disrupt its equilibrium between the sustainable dimensions of the development process.

This E.S.O. induction model has been illustrated for Indian population recovering from volcano hazard (Woloszyn *et al.* [29]) or in consequences of settlement mistakes on vulnerability from storm Xynthia in French west coast (Woloszyn *et al.* [30]) as well as 2012 US drought event which will be described following.

United States underwent a widespread drought on 2012's summer. This climate event, as severe as the historic drought of the 1950s has caused huge damages within pasture and rangeland. The US Department of Agriculture (USDA) designated even more drought disaster areas, bringing the total for the 2012 crop year to 1369 counties in 31 states (Figure 5).

With more than 40% of US agricultural land in extreme or exceptional drought, "Prices of both corn and soybeans soared to all-time highs, with corn climbing more than 50 percent in the past four weeks alone due to the worsening drought, squeezing livestock producer margins." (Reuters, July 20, 2012).

As said Bruce Williams, Kansas-Phillipsburg agricultural cooperative director: "since 31 years doing this business, I never saw such prices fluctuations" (Reuters, August 28, 2012), it is not the price level that borrows producers, but their fluctuation periods, which have passed from seasonal (between summer and winter, namely) to daily frequency, which causes market uncertainty by unpredictable price variations, thus increasing entropy of the whole eco-social system.

This first (Organic-Economic) induction effect sawn Figure 6 will then be followed with a second (Economic-Social) induction effect (Figure 7), thus squaring the vulnerability-sustainability triangle to enter a first induction phase leading to global crisis emergence.

5. Community Resilience as an Answer to Territorial Vulnerability

5.1. Resilience to Draught? The Case Study Concludes

While drought planning and mitigation responsibilities lie largely at the state and local level, the federal government also provides some drought planning assistance. In that aim, US Secretary of Agriculture sets in motion a series of alerts, recommendations, activities, and possible restrictions at the local, regional, or state level, depending on the drought length and severity. Ultimately, a multi-year severe drought could initiate a federal response and transfer of federal dollars to the affected area.

In response to the 2012 drought, USDA also has taken a variety of administrative actions, such as interest rate reducing or a rental payments reduction. Congress may evaluate whether current federal practices could be supplemented with actions to coordinate, prepare for, and respond to the unpredictable but inevitable occurrence of drought. In passing the National Drought Policy Act of 1998, US Congress may consider proposals to manage drought impacts, such as assisting localities, industries, and agriculture with developing or augmenting water supplies (Folger, Cody, & Carter, 2012 [21]).

By increasing economical capacitance of agricultural product units (farms), the federal government enable

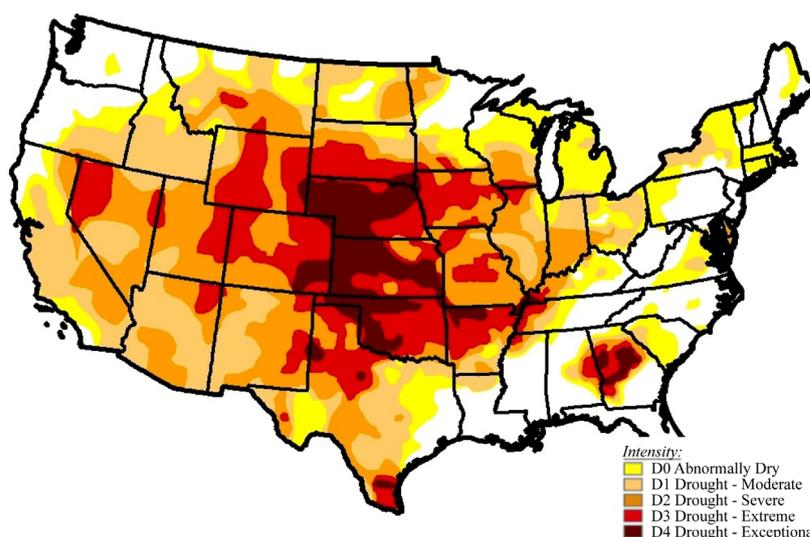


Figure 5. US drought monitor (Reuters, August 30, 2012).

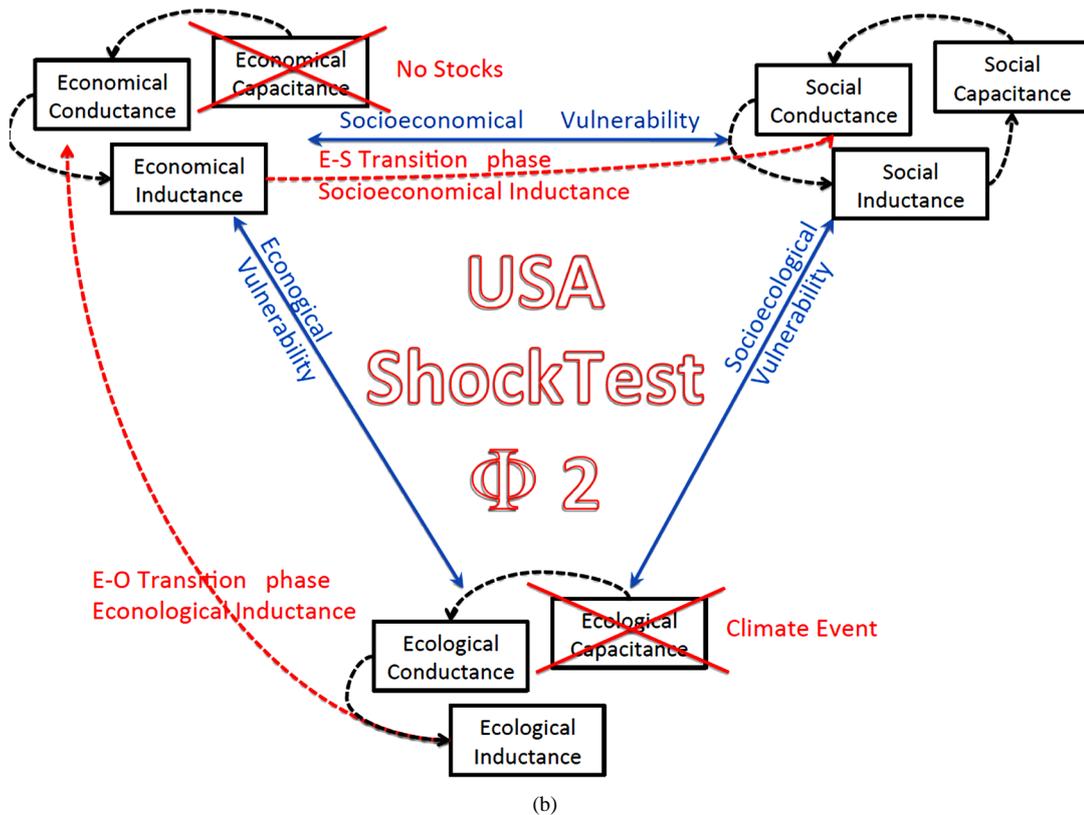
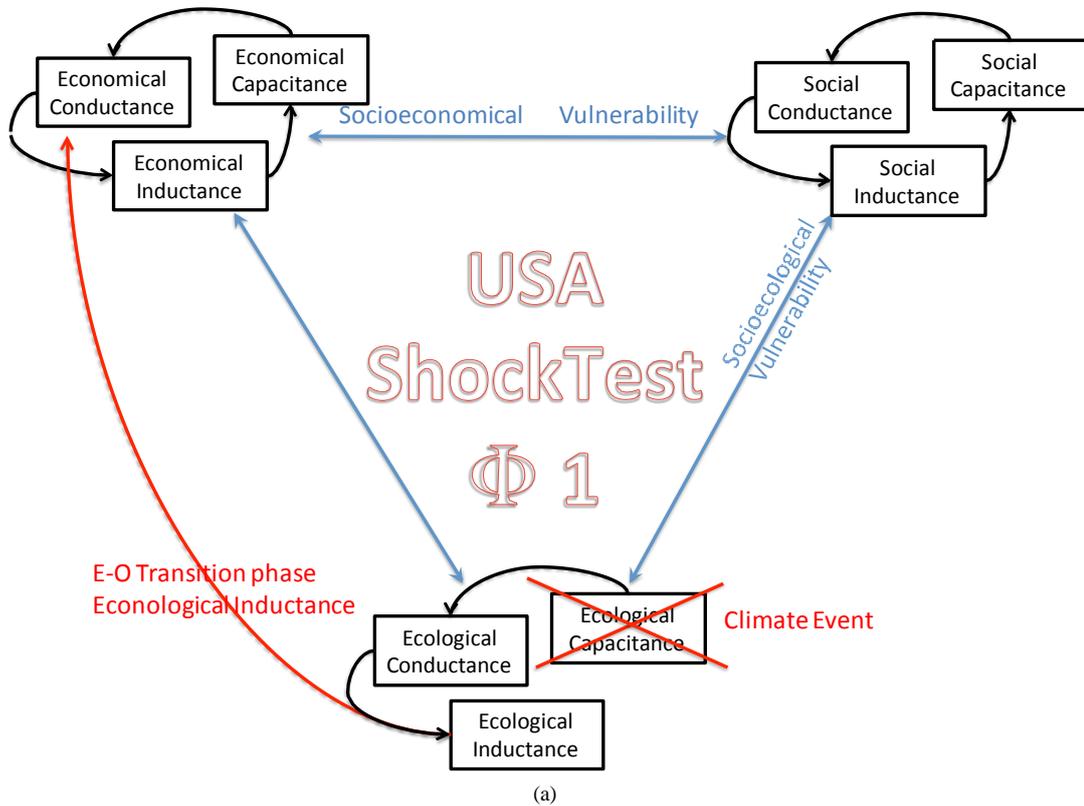


Figure 6. First (organic-economic) induction effect: phases 1 & 2.

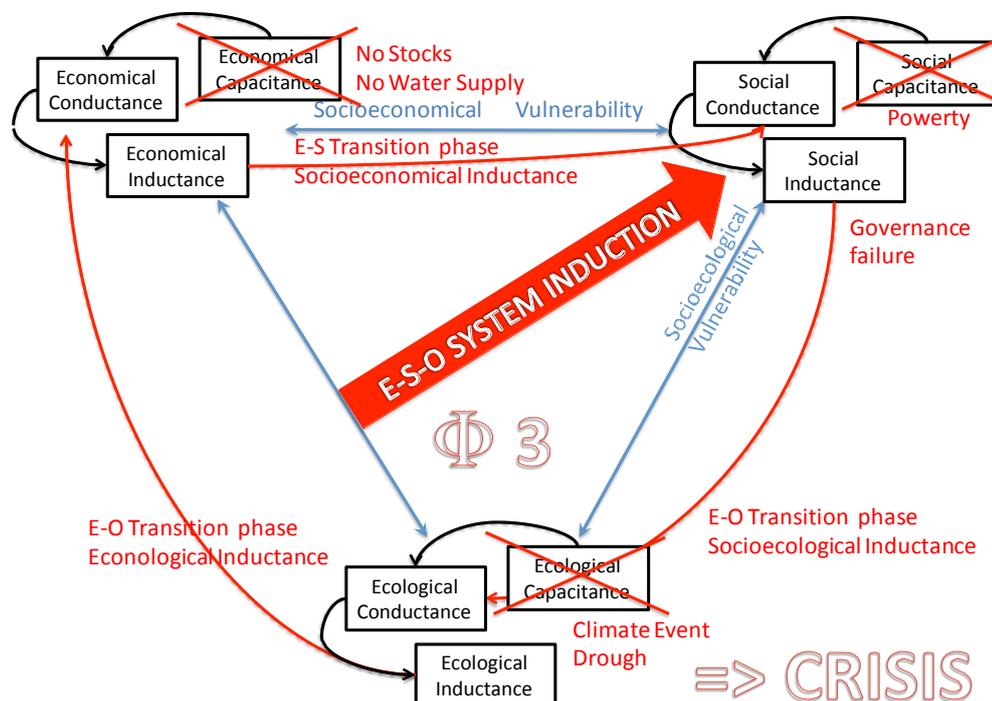


Figure 7. Second (economic-social) induction effect: phase 3.

socioeconomical resilience to increase social capacitance, and therefore, to avoid social risks due to insufficient feeding supply. If this governance action increases the inductive fields of socioeconomical actions, this short-term federal response has to be completed with long-term policy rules concerning land use, pollutant emissions, and environmental preservation, in order to enable socioecological resilience to “square” the whole E.S.O. system resilience (Figure 8). As a major consequence, to solve climate-related production problems, the way people act together through coordinated cooperative actions will be essential for eco-social capacitance long-term increasing, and therefore, resilience induction enabling.

5.2. The Role of Territorial Policies and Territorial Cooperation Actions

This case study clearly establish the inference from ecological crack-up to economic or financial crisis and social-cultural recovering assets, thus underlining innovative policy rules mechanisms through “eco-social” inventions such as collaborative actions. In this example, resilience appears to formalize a paradigmatic change of natural risk treatment, which response to systemic crisis like drought, has to be scaled from local level, at relatively short time scales (*i.e.* implying people’s cooperation or cultural patterns negotiation) to long-term global level.

At this level, state securing is a necessary condition to resilience process, but could not endorse the sole response to eco-socio-economical vulnerability. Considering territorial resilience as a reaction conditioned by vulnerability, governance systems have to deal differently with population’s attempts and demands, so to deal with involvements wishes, participation appraisal, or with inhabitant’s empowerments. This constitutes a noticeable fact throughout the world: decisions making processes and regulation tools have been progressively adapted to environmental or social risks. Moreover, when governance fails to non-completion of the principle of subsidiarity, to ensure the conditions of sustainability, territorial policies transfers their competence to the local cohesion of the regional identities. Most of the time, this transfer is achieved by associating the processes of singularization, namely collective actions (Stiglitz [32]), with the implementation of territorial policies. In a transverse way, achieving sustainability goals through effective economic, social and institutional reforms as a route to sustainability transition seems actually insufficient (Raskin *et al.* [24]). As a consequence, articulation between local monitoring and global governance constitutes a dialectical answer to the resolution of crisis through involving territorial cooperation action.

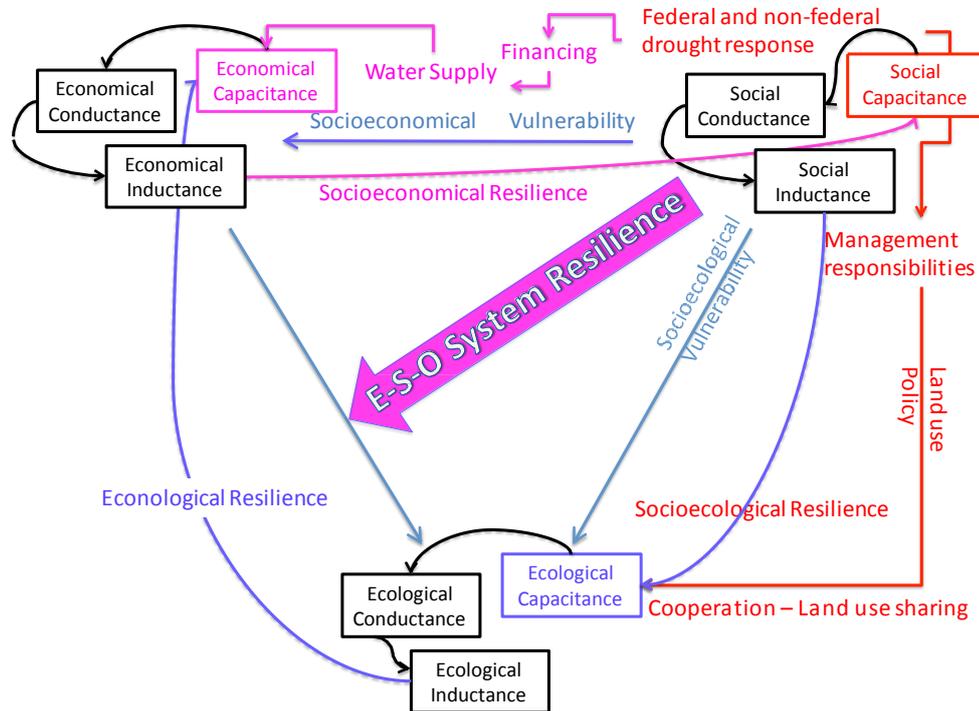


Figure 8. E.S.O. resilience system for US 2012 drought.

The contribution of territorial information systems to fair governance and to a sustainable development requires both data availability and adapted territorial decision information processing. Common accessible territorial knowledge, supported by an interdisciplinary scientific coordination, is the necessary prerequisite for collective construction of spatial co-action. Therefore, adaptive capacity of societies for territorial resilience requires new political schemes and regulation tools, namely participative processes, involving people capabilities (Sen [33]) and democratic innovations such as controversies methods (Faburel [26]).

In order to allow the emergence of this cooperative process at a territorial scale, territorial intelligence (Girardot [34]) has to recover the immaterial values of local cultures. Territorial intelligence acknowledges implicit qualities and uniqueness heterogeneous local societies, by promoting specificities of the territory. Thus, vulnerability recovering processes for socio-ecological transition needs managerial reflection upon local singularities in a general perspective of a transition model of development. Therefore, introducing political priorities for local action and adapt public action goals to the socio-ecological new ideal is the main condition for territories resilience strengthening. With adopting a holistic systemic viewpoint, indicators of system “state” may help to realize this interactional measurement with sustainability entropy measurement.

5.3. Entropy Maximization as a Way to Optimize Socio-Ecological Transition

To proceed to economical/sociocultural/ecological coefficients valuation through entropy measurement, an approach of this “Triple bottom line” structure of sustainability could be achieved through informational dimensioning of: 1) economical macro and microeconomic dynamics (Stiglitz *et al.* [35]), 2) population-wealth distribution (Wolff [36], Davies *et al.* [37]), and 3) ecological human footprints (Ayres [38], Costanza [9]), as illustrated Figure 9. Each of those dimensions should enable to solve a criticality matrix of socio-ecological transition process by its resilience entropy valuation.

To achieve this goal, Wissner-Gross and Freer [39] proposed a “first step” to implement entropic conception of intelligence from the entropy maximization general formula:

“Causal generalization of Entropic forces may spontaneously encourage remarkably sophisticated behaviors, for example participative processes, collaborative initiatives or globally social cooperation, associated with the man living in his cognitive niche” (Wissner-Gross & Freer [39]).

Whether at the global or local scale either upstream or downstream of the occurrence of problems, socio-

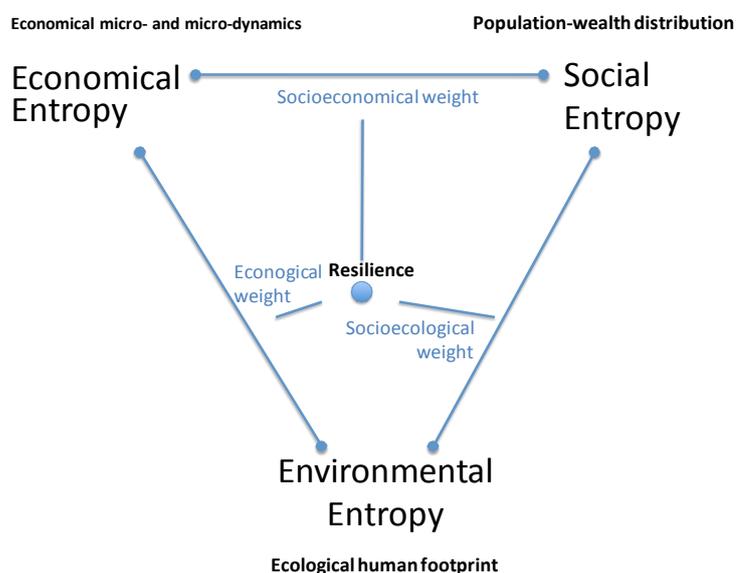


Figure 9. Sustainable development entropy combination for resilience valuation.

environmental vulnerabilities have to be solved by managing methods and operating modes of territorial development at different scales, thus constituting one of the main drivers of social innovation, to enable a successful socio-ecological transition process.

6. Conclusions

Beyond its crisis process modelling capacity in the three dimensions of sustainable development, the main contribution of this sustainable development convergence model is to manage values systems that may admit many incompatible a priori solutions. Indeed, this outstanding model property should allow resilience process to be simulated at territorial levels.

To achieve this goal, complementary directions of this study will complete the inductive model calibration by empirical observations, stakeholders listening, discourses analyzing and practices survey, in order to propose decision scenarii leading to sustainability paths of development. Thus, construction of a viability framework should provide descriptions of the possible consequences of policies, decisions and actions following a hazard or an environmental change at a territorial level. Further developments will propose a mathematical framework of inductive entropy maximization based on viability theory to foster operational ways of resilience through producing coordinated responses in the three dimensions of sustainable development to environmental changes.

Hence, reaching sustainability goals through effective economic, social and ecological reforms as a route to the sustainability transition may enable societal anticipation and socio-cultural response to environmental constraints and shocks.

7. Acknowledgements

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