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The PISA grammar decodes diverse human–environment approaches

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ABSTRACT

Human–environment interactions are studied by several groups of scholars who have elaborated different approaches to describe, analyze, and explain these interactions, and eventually propose paths for management. The SETER project (Socio-Ecological Theories and Empirical Research) analyzed and compared how "flag-holders" of distinct school of thought in human–environment scholarship approached a number of empirical problems of environmental management. This paper presents the findings from this experiment by concentrating on how representatives of four schools of thought approached one of these case studies: the plant health crisis in greenhouse tomato production in south of France. Our analysis suggests that these approaches share a common conceptual vocabulary composed of four explanatory elements of change (Power, Incentives, System and Adaptation-PISA). We argue that what distinguishes these schools from one another is the syntax—the "rules" by which researchers in each of the sub-disciplines tend to organize the components of this shared conceptual vocabulary. In other words, the schools under scrutiny are differentiated not so much by what they speak of, but rather in what order, or hierarchy, do they tend to rank the importance and/or the sequence of each of these concepts in human–environment explanations. The results of our experiment support the view that communication and cooperation across the diverse human–environment traditions is possible and productive. At the same time, however, we argue that it is the distinctiveness of the claims yielded by these different schools of thought that augment our collective understanding of complex socio-ecological problems. Attempts to integrate these perspectives in one unitary approach would undermine the intellectual wealth necessary to meet the challenges of the Anthropocene.

1. Introduction

Human–environment interactions are studied by several groups of scholars who have elaborated different approaches to describe, analyze, and explain these interactions, and eventually propose paths for management. These groups of scholars are more or less loosely organized around core concepts or sub-disciplines that include adaptation (Smit and Wandel, 2006), vulnerability (Adger, 2006; Turner, 2002), resilience (Folke, 2006; Holling, 1973), common-pool resources (Ostrom, 1990), and political ecology (Blaikie, 1999a; Greenberg and Park, 1994; Wolf, 1972). Despite considerable overlap in their object of study, these sub-disciplines tend to be based on different disciplinary backgrounds, meet at different conferences, and publish in different journals than one another, forming more-or-less distinct "epistemic communities". The Socio-Ecological Theories and Empirical Research project (SETER) sought to assess how these theoretical frameworks relate to each other and their respective contribution to the resolution of human–environment problems. To this end, we analyzed and compared how "flag-holders" of distinct school of thought in human–environment scholarship approached several empirical research case studies developed by four different units of international research centers based in Montpellier, France. In addition to clarifying the respective potential of the different theoretical frameworks, this assessment also sought to consider the possibility of new conceptualizations of socio-ecological interactions that integrate these diverse perspectives. The project was organized around sets of workshops, in Montpellier, France. Twelve senior researchers in the field of human–environment interactions stayed in Montpellier to analyze the different cases

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studies with a given approach. The visiting scholars[1] were grouped in teams, asked to represent–or "hold the flag of"–one approach on the interactions between society and nature coming from the disciplines of ecology, economics, geography, sociology and political science. In total, seven approaches were considered (political ecology, resilience, vulnerability, complexity and common-pool resources, biodiversity and ecosystem services, robustness, mental models). Each team was presented the same set of four case studies by the respective Montpellier-based research units. On average each scholar worked for 15 h with a given case study.

The SETER project and its results are discussed in greater details elsewhere https://hal.archives-ouvertes.fr/hal-01130178. This paper is focused on a more specific set of questions emerging from that project: (1) what are the central precepts of these different approaches to human–environment scholarship?; (2) what are the differences between the approaches?; and (3) what are the implications of these relations between the different approaches for the relevance, and possibility of their integration?

Our analysis of the responses and approaches to the case studies by representatives of these four human–environment perspectives suggest that these approaches share a common set of explanatory elements of change: what can be thought of as a common vocabulary. Many if not all the core concepts and analytical concerns used and expressed by workshop participants in their treatment of the case studies have some counterpart in how representatives of other perspectives approached the same cases. What sets these schools of thought apart from one another, we argue, is best described not as different vocabularies but rather as different syntaxes of a common conceptual grammar: the "rules" by which researchers in each of the sub-disciplines tend to organize these explanatory elements. In other words, these human–environment perspectives are differentiated not so much by what they speak of, but rather in what order, or hierarchy, do they tend to rank the importance and/or the sequence of each of these concepts in human–environment explanations.

To illustrate what we mean by common conceptual vocabulary and different syntaxes we focus on four schools of thought (political ecology, resilience, vulnerability, complexity and common-pool resources), comparing how they each relate to a common case study of the SETER project that is particularly illustrative of how the different schools of human–environment scholarships compare to one another: the problem of the whitefly *Bemisia tabaci* for Tomato production in Southern France. Following a brief description of the four schools of thought under consideration and of the concepts recurrent across all schools, we illustrate the different ways in which scholars using these schools tend to organize or rank these different concepts to explain human–environment interactions. Then, we discuss some implications of these results for attempts at integration and collaboration across these various human–environment schools. Our conclusion is that these diverse approaches to the complex and varied human–environment problems share a common set of concepts that make transdisciplinary dialogue and collaboration not only possible but highly rewarding. Hybrid approaches derived from such collaboration can and do foster new understandings to resolve problems in ways that would not be possible otherwise. The differences between these diverse schools of thought in emphasis, assumptions, and primary concerns, allow each perspective to bring something different to the table. Our analysis highlights that human–environment scholarship is enriched, rather than diminished, by the co-existence of these simultaneously compatible yet largely autonomous approaches, and that attempts to integrate this diversity of approaches into one would be counter-productive.

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2. The case study: greenhouse tomato production in Southern France and the Bemisia fly

In France, tomatoes produced for the fresh market are mainly grown in heated greenhouses with long cycle of continuous cropping (11 months). More than 45% of all French-produced tomato are grown in the Rhône-Mediterranean basin. Before the year 2002, 80% of growers were controlling tomato pests using Integrated Pest Management methods based on biological control (IPM-BC), a strategy that uses few insecticides. The popularity of IPM-BC in tomato production is encouraged by shifts in consumer preferences. These preferences are no longer limited to the quality of the tomato itself, but also include concerns about the environmental and sanitary conditions of production. In a context of internationalization of markets, the organoleptic qualities and the sanitary status of fruits and vegetables, the ecological sensitivity of their production, and the freshness of products, are increasingly important priorities for consumers and producers alike. This is tied to priorities of customers and professional organizations (e.g., ONIFLHOR, "Office National Interprofessionnel Des Fruits, Des Légumes Et De L'horticulture"), that consider both the freshness of a given product and the limited environmental impacts of its production as predominant indicators of said product's contribution to personal health ("fresh product = health factor") and ecological sustainability. Progress in Biological and Integrated Protection over the last 20 years, especially in tomato production, has greatly helped producers meet these changing demand for ecologically sensitive agriculture (Van Lanteren, 2000). Growing restrictions on the use of chemicals in agricultural production, especially at the European level, are also part of this changing context. The adoption of IPM-BC is thus conform to the European policy of pesticide reduction, which is strongly recommended by the Fresh Fruits and Vegetables Agency (http://www.aprifel.com).

In 2002–2003, Southern France tomato growers saw their crop devastated by a new pest insect: the small whitefly *Bemisia tabaci*. This cosmopolitan and polyphagous pest insect species has a very large range of host-plants and attacks ornamental as well as horticultural crops. The fly causes significant direct damage to plants, but it is considered a pest hazard primarily because of its role a disease vector: *Bemisia* can transmit more than 110 phytoviruses, including some that are very harmful, such as the Tomato Yellow Leaf Curl virus (*TYLC*) (Moriones and Navas-Castillo, 2000).

The sudden outbreaks of *B. tabaci* populations in Southern France's tomato-producing greenhouses in 2002–2003—and the *TYLC* virus carried by the insect—generated a major phytosanitary (plant health) crisis (Fargues et al., 2004). The presence of TYLC-infested Bemisia on tomato plants posed problem to IPM-BC, undermining progress made in that field over the last twenty years. The *TYLC* problem was already known in other tomato producing countries such as Spain, but the 2002–2003 outbreak in France was new for that country. French authorities responded by rapidly classifying the virus as an agent of quarantine and supplemented European directive on the spread of viruses by ordering obligatory control of *TYLC*. Producers of TYLC-infested crops had to report infestation to the national Plant Protection Agency services (SRPV) and destroy the crop, for which they were to receive no compensation. This Bemisia-TYLC outbreak profoundly destabilized the entire production channel of tomato in France (Dalmon et al., 2003). In sum, the emergence of Bemisia-TYLC constitutes a phytosanitary crisis: the introduction and establishment in France of an insect of tropical origin, vector of phytoviruses harmful to ornamental and horticultural crops of great economic importance in invasion-prone areas.

This phytosanitary crisis is also taking place within a context of warming climatic conditions in France, where summer heat waves are increasing in frequency and magnitude. The warmer temperatures of June and July usually generate ideal conditions for the introduction, establishment, and extension of Bemisia-TYLC spots. The increasing occurrences of heat waves, such as the one observed in 2003, raise concerns about the sustainability of tomato crop productions in greenhouses in the Rhône-Mediterranée basin and principally in the Roussillon region.

The risk of Bemisia-TYLC became therefore a question of research and development, with important scientific stakes for researchers and economic stakes for producers, consumers, and political authorities. And again, the emergence of this phytosanitary crisis in a context of global climate change challenges conventional approaches to safety, productivity, efficiency, and equity in fruit and vegetable production. Doing so, it calls for an interactive scientific community capable of (1) analyzing the technical and organizational aspects facing the management of major phytosanitary risks dues to bioinvasions and (2) anticipating and overcoming global change impacts.

3. The SETER project results: the grammar of human–environment relations

By analyzing how scholars of different human–environment perspectives (schools of thought) approach a common selection of environmental problems, the SETER project inductively elicited commonalties and divergences in logics, language, and tendencies across these perspectives. The results reveal a shared conceptual equipment, which we refer to here as vocabulary and grammar, accompanied by differences in the rules that assemble these components, which we refer to here as syntax. We briefly introduce the perspectives and how they respectively approach the Bemisa case study, after which discuss what this experiment reveals on how these human–environment dialects relate to one another.

3.1. Human–Environment schools of thought' perspectives on the case study

3.1.1. Political ecology

According to Paulson et al. (Paulson et al., 2003), political ecology was developed on a set of key ideas: (1) the idea that use of and access to resources are organized and mediated by social relationships that might impose a production rhythm that might be harmful to the environment (Watts, 1983); (2) the recognition of different positions, perceptions, interests and rationalities in relation to the environment (Blaikie, 1999b); (3) the idea of connectivity across scales, which implies that local processes are influenced and influence global processes (Escobar, 1999), and (4) the idea that social exclusion is the result of mutually reinforced political economic and ecological processes (Blaikie and Brookfield, 1987). Based on the work of several scholars (Forsyth, 2003; Robbins, 2004; Blaikie, 1999a; Zimmerer and Basset, 2003; Peet and Watts, 1996; Stott and Sullivan, 2000), two main currents within PE can be distinguished. The first comprises empirical work on environmental activism related to struggles for resources and the formation of the state. This type of research provides a thorough analysis of environmental resistance of certain social groups (Bryant, 2000; Bryant and Bailey, 1997). The second approach involves research about the construction of the environment as a discourse and the role of discourse and political action in the establishment of accepted definitions (Peet and Watts, 1996; Watts, 1983; Peluso and Watts, 2001).

The Bemisia case study was analyzed by political ecology scholars as "*an example of the agricultural neo-liberalization process with:*

a *An ideological commitment to the reduction in state power relative to markets.*
b *A shift of risk and responsibility to individuals, simultaneous with a change in regulatory regimes to favor trade.*
c *Shifting accumulation regimes, typically to concentrated and large firms and to "off-shore" production sites, with cheaper labor markets and more relaxed environmental regulations.*

The conceptual model of Bemisia case study is a model of «risk regime». The current risk regime is poised for an undesirable major outbreak following a heat wave or other stochastic event. The risk regime is locked into place by interests that benefit from, and are rewarded by the current pattern of accumulation and management" (more in Appendix 1).

3.1.2. Vulnerability

Vulnerability has emerged in recent years as one of the central organizing concepts for research on global environmental change (Mccarthy and Canziani, 2001; Turner et al., 2003). Vulnerability is defined as the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress, accounting for adaptive capacity. The vulnerability approach demands attention to human–environment interactions along three dimensions: exposure, sensitivity, and adaptive capacity. Exposure refers to the interaction of the hazard with the system. Sensitivity refers to the short-term impacts and responses and conditions mediating the production of the impacts following the exposure. Adaptive capacity refers to current and future abilities and inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses.

For a vulnerability scholar examining the Bemisia case study, the overarching research question necessary to look at the Bemisia-tomato relationship was: "*what explains the vulnerabilities of the regional tomato production system associated with climate variability and change (the frequency and magnitude of heat waves and droughts)? Questions pertaining to exposure included: what is the occurrence of droughts? How many tomato producers are in the region, what is their production capacity, and where are they located? For sensitivity: How much did tomato production/profits decline for regional producers in 2003? Which producers stopped growing tomatoes after 2003? What is the variation of Bemisia population relative to temperature in the field? Do regional tomato producers produce other products? And for adaptive capacity: what do the farmers who grew tomatoes in 2003 produce today? What is the status of "collective action" institutions related to tomato production?*" (more in Appendix 1)

3.1.3. Resilience

The resilience perspective emerged in ecology in the 1960s and early 1970s. In an influential paper on resilience and stability in ecological systems, ecologist C.S. Holling illustrated the existence of multiple stability domains or multiple basins of attraction in natural systems and how they relate to ecological processes, random events (e.g., disturbance) and heterogeneity of temporal and spatial scales (Holling, 1973). With this new perspective research shifted the focus to transitions between the stability domains and emphasizes variability and system dynamics rather than stability. Following Carpenter et al. (Carpenter et al., 2001) social–ecological resilience is understood as (1) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction, (2) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors), and (3) the degree to which the system can build and increase the capacity for learning and adaptation. There is an increased emphasis on the notion of transformability ("The capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable.") into improved social–ecological systems as opposed to adaptation to the current situation ("ability of systems to absorb changes of state variables, driving variables and parameters, and still persist"). An emphasis on transformability implies extending the focus in social–ecological research to systems of adaptive governance (Dietz et al., 2003) in order to explore the broader social dimension that enables adaptive ecosystem-based management.

On the Bemisia case study, resilience scholars participating in the SETER workshops explained that "*the theoretical framework of resilience focuses attention on the system's key variables, by scale and sector, and how these factors interact and generate shifts between TYLC outbreaks and senescence. Resilience-thinking points to research questions on the tomato-Bemisia outbreak system that might include: (a) what can be learned about the regional spread of TYLC from greenhouse to greenhouse, (b) what are the mechanisms of predator control, (c) how might the problem evolve under changing and uncertain conditions (e.g., climate change), and (d) what can be learned from the outbreak crisis, specifically with respect to the role of compensation as subsidizing pathology or forcing adaptation. More theoretical questions would relate to managing for specific vs. general resilience (i.e., specific resilience of tomato production system to TYLC vs. general resilience of greenhouse food production to future pest outbreaks and other unforeseen events). Finally, what can be learned from the case study about trade-offs in managing systems at the edge of stability domains*?" (more in Appendix 1).

3.1.4. Commons and complexity

The commons and complexity approach to human–environment relations has roots in earlier work on collective action in natural resource management and the difficulty of governing shared resources (Gordon, 1954). Whereas conventional analyses based on classical economics assumptions about human behaviour often suggest that commonly held resource are prone to be mismanaged lest they are privatized or rationalized, empirical studies examining the different ways commonly-held resources are managed have shown that, under certain conditions, collective management by user groups can be more adaptive and attuned to ecological shifts and change affecting resource systems than private allocations or externally imposed management regimes (Ostrom, 1990). Besides finding that self-governance not only does happen but also often lead to better results than externally imposed regulations, scholars in this field have contributed to a better understanding of the factors that contribute to success of collective action (Ostrom, 1990). Ostrom and her colleagues developed over the years a framework that examines how human behaviour co-evolves with micro-situational variables and other elements of the broader context (Poteete et al., 2010). This general framework focuses on the tension between individual and group interests. The societal interest in collective action is, under certain conditions, undermined by individual interest to (1) not contribute to group effort while (2) still benefiting from these, i.e., "a free-ride" This tension highlights the importance of the institutional arrangements that encourage individuals' contribution to the common good, monitor outcomes, and sanction rule breaking. In this context, the commons and complexity approach could be understood as one that asks: how do resource-users craft institutions for collective action attuned and adaptive to the given social–ecological context? The analysis of case studies follows a diagnostic approach where broad themes of social and ecological components of the social–ecological system are investigated before digging deeper into the specific attributes of the given system. The complexity is caused by the interdependencies of the attributes of the system at different scale.

For "commons and complexity" scholar in the SETER workshops, the tomato-Bemisia case-study invited attention on how producers interact with institutional incentives. As one participant put it: "*Given insights in attributes of producers, which incentive structures can lead them to practice preventive actions? The hypothesis is that the farmers are highly risk seeking, have low trust in other producers and governmental entities. These producers are able to move from one high-gain, high-risk production system to another, especially by harvesting subsidies. The agricultural systems have evolved to go through overshoot and collapse cycles. The question is: what institutional incentives lead to this type of 'agents'? The*

Table 1
The elements of change in human-environment analysis. The cells under the "unit of analysis" indicate the type of action for a given explanatory element of change (i.e., under I explanatory element of change an actor will select among incentives, while under A explanatory element of change it will respond to the stimulus).

Explanatory element of change	Unit of analysis					Role of the analyst: to identify the . . .	Objective of the associated management interventions (if any)
	Actor	Group of actors	Social groups	Interaction configuration	Biophysical and ecological environnement		
Incentive structure (I)	Select among incentives	Select among incentives	Not the focus of analysis	Not the focus of analysis	Not the focus of analysis	incentive structure and document it	To orient (secure) the actors' decisions
System trajectory (S)	Not the focus of analysis	Not the focus of analysis	Not the focus of analysis	Evolves	Not the focus of analysis	components and their interactions	To orient the trajectory toward desirable states
Adaptation (A)	Responds to the stimulus	Responds to the stimulus	Responds to the stimulus	Responds to the stimulus	Responds to the stimulus	exposure, sensitivity & adaptive capacity	To decrease exposure and sensitivity, increase adaptive capacity
Power and control (P)	Not the focus of analysis	Not the focus of analysis	Not the focus of analysis	Controls	Not the focus of analysis	Social & political relationships	To modify the control configuration

suggestion is to perform survey analysis (including decision experiments) on risk attitudes and trust. The experimental problem (high gain, low probability of big negative effects) would test different incentives structures, for example conditional subsidies". (more in Appendix 1).

3.2. The shared vocabulary: four explanatory elements of change

The main conclusion of SETER project is that, by comparing the different contributions of each school of thought and what they respectively include or omits, we identify four explanatory elements to analyze change in human–environment interaction (Table 1).

The four shared explanatory elements of change are presented here as parts of a common vocabulary used by scholars in the four schools of thought discussed in this paper. First, each school of thought highlighted the decision contexts, stressing both incentives for certain kinds of decision-making and constraints on the "practical range of choice"(Turner, 2002). We designate this explanatory element with the letter "I", for incentive. There is an emphasis on cognition: the actor will make an interpretation of his or her context. The task of the scholar, then, is to understand how actors get information and build the incentive structure which constitutes the possible choices. Second, the four approaches shared an interest in and acknowledgment of the ways objects (e.g., plants, flies, farmers, regions) are sensitive to external pressure and adapt to changing conditions. We designate this explanatory element as "A", for adaptation. The task of the scholar with regard to this explanatory element is to understand how the target entity will respond to perturbations, depending on its sensitivity and adaptive capacity. The third explanatory element shared by all approaches focuses on system states, feedbacks, and equilibrium/disequilibrium: the "S" (or system) explanatory element. Scholars address these explanatory elements by asking (1) how are the components assembled, and (2) how is the resulting evolving or likely to evolve. Finally, all approaches shared some level of concern or acknowledgment of the uneven distribution of power and control between groups, actors, or institutions, and the concomitant force relations emerging from their interaction, signified here as the "P" (or power) explanatory element.

Each of these explanatory elements (rows in Table 1) favors different units of analysis (columns in Table 1). Traditionally, when dealing with the relation between groups and their environment, one considers the following units of analysis: (1) the actor, (2) the group of actors seeking common objectives (managing the resource, solving a problem, selling products, etc.) named here "actors group", (3) the social group, which is a group of individuals who, though heterogeneous, broadly share values, history, culture, (4) the "biophysical and ecological environment", which is characterized by specific dynamic interactions between processes. Finally for the present analysis we add another entity which is the "interaction configuration". We could have called this the "system" but the systemic view is more closely associated with one approach and is not a relevant for all approaches. Table 1 also includes two additional columns. The first column describes the role of the scholar analyzing change in each of the perspectives (e.g., to identify the sets of incentive structuring actors' decisions, the components of the system and how their interactions explain the trajectory of the system). The last column to the right indicates the type of management intervention associated with the explanatory element of change. This relates to the intention of the analyst. For instance an analysis based on incentive structures would lead to management interventions (if any) aiming at orienting actors' decisions through knowledge and information.

3.2.1. The "Incentive and Constrained Decisions": explanatory element I

All analysts in the workshop operated under assumptions about, and paid attention to, how incentives and constraints shape human decisions. This directs focus on "actors" and the collective environment in which they are situated. Actors have the capacity to make choices (agency), yet incentives and constraints shape their decisions. Collective change emerges from the aggregation of these behaviors. Analysts using each of the four approaches stressed that understanding the constraints and incentives that shape this decision-making was important to describe and understand the human–environment problem presented by the Bemisia invasion. The quality of contextual information, the mental model of what other actors may do, and the trust that allows them to anticipate one another's actions are necessarily important factors. Actors may act independently within these constraints, leading to disorder (Hardin, 1968), but they may also share information, points of view, and possibly decide together on rules to collectively constrain their behaviors and produce a desired change (Ostrom et al., 1994). This emphasis is typically associated with behavioral economics but it is also found in numerous other social sciences fields including social psychology, human geography, and environmental anthropology. The notion of constrained choice is not unique to any school, therefore, and can be seen in multiple interpretations of the Bemisia case. Across the different scholars' analyses of Bemisia case we observed this reference repeatedly, as the following statements from representatives of each of the approach illustrate:

- *"The producers are able to move from one high gain high risk production system to another," (commons & complexity)*
- *"Experiments could be done. Given insights in attributes of producers, what are incentive structures to lead them practice preventive actions? Experimental problem: high gain, low probability of big negative effects. Test different incentives structures: for example conditional subsidies." (complexity & common-pool resources)*
- *"Does compensation subsidize pathology or force adaptation?" (resilience)*
- *"Are there disincentives to applying for state compensation, and if so, do these disincentives result in farmers not reporting the presence of the fly?" (vulnerability)*
- *"Compensation could be seen as an overamplification, because the incentive of the farmers might be to declare even more to get more compensation" (complexity & common-pool resources)*

3.2.2. The "Adaptation & Sensitivity": explanatory element A

The second shared explanatory element of change that we identified stresses the response of an entity to external stimuli, disturbance, impact or influence. Here, the central concern is the way in which the entity (e.g., community, forest, pond) is exposed to disturbances (e.g., hazards, regulations, temperature changes) and responds. Using a language imported from biology, adaptation supposes that an object undergoes a stress, caused by an event that can be either endogenous or exogenous. The set of possible changes is associated to the given perturbation, whereas the response depends on the adaptive capacity of the entity. These metaphors have their origins in the natural sciences, reflecting the influence of an evolutionary logic, based on the reproduction and survival of a system (Smit and Wandel, 2006). Change is driven by the mechanism of selection: the survival of the perturbed object depends on how much it fits with its environment. One implication of such an explanation is that the object submitted to stress does not have the responsibility of its response. A second implication is that such an explanation does not pay attention to the effects of perturbation on other objects or the effects of the entity's response “downstream” onto other objects. Investigations into these relations may seek to understand the degree to which processes at other levels contribute to the sensitivity of the entity or its adaptive capacity. Some acknowledgment of and concern for adaptation was evident in all analyses of the SETER cases. Analyses from multiple perspectives shared this common reference to a degree, as the following phrases illustrate:

- *“What are the adaptive capacities of the farmers?” (complexity & common-pool resources)*
- *“The sensitivity is the short-term impacts/responses & conditions mediating the production of the impacts following the exposure. How much did tomato production/profits decline for regional producers in 2003? Which producers stopped growing tomatoes after 2003? What is the variation of bemisia population relative to temperature in the field? (. . .) The adaptive capacity is current/future abilities & inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses. What do the farmers who grew tomatoes in 2003 produce today? What is the status of “collective action” institutions related to tomato production? Have these institutions actually helped a significant number of individual tomato farmers in recent times of “crisis”?” (vulnerability)*
- *“The current risk regime is poised for an undesirable major outbreak following a heat wave or other stochastic event. That regime is perpetuated by a few specific conditions”(political ecology)*

3.2.3. The “System Trajectory”: explanatory element S

In each case, moreover, there was a consistent interest in describing and tracking the interactions between elements as a whole, often invoking the language of a “socio-ecological system”. The “system” is typically viewed as an aggregation of different processes, actors, stocks and flows, with ecological and social components, integrated and interacting with other components, constituting a larger whole. It is assumed that the system will shift as a whole, depending on the arrangement of its internal components. The stress in this moment of analysis is on the overall momentum within a socio-ecological arrangement that drives it into new states: here, the important questions lie in the trajectory of transitions from one state to another and the conditions that predicate positive or negative feedbacks, or shifts between equilibrium and disequilibrium periods.

Though some approaches, especially resilience thinking, are couched most formally in the language of systems (e.g., feedbacks; slow and fast variables), *all* of the observed approaches demonstrated some tacit enunciation of system behavior in their consideration of the Bemisia/tomato complex. The following phrases are indicative:

- *“The agricultural systems have evolved to go through overshoot and collapse cycles.” (complexity & common-pool resources)*
- *“There are two stability domains: Producers who have labor intensive (subsidized) production of organic food of many different types: lower production, but more resilient. Producers who have capital intensive production of monocultures. High gains, but reasonable probability of collapse. Typically effective to get governmental support to continue.” (resilience)*
- *“The key components of the system are ...” (resilience)*
- *“Finally, what can be learned from the case study about tradeoffs in managing systems at the edge of stability domains?” (complexity & common-pool resources)*
- *“The conceptual model is a model of « risk regime ». This regime is due to the events on 2004. The risk regime persists because there is accumulation somewhere in the system. (political ecology)*
- *“The risk regime is locked into place by interests that benefit from, and are rewarded by, the current pattern of accumulation and management. “ (political ecology)*
- *“The consequence of this absence of trust if the fact that farmers suppress information, there is no more sensor, no more feedback and this system cannot be controlled. It becomes very fragile.” (complexity & common-pool resources)*

3.2.4. The “Power and Control”: explanatory element P

This shared element of human–environment explanation focuses on the force relations governing interactions. It does not stress the integrated unit as a whole but rather focuses on the structured interactions between elements, individuals, and groups. What become most central here is naming and describing issues of access and control over components. This informs analysis that describes and explains the encounter, interactions, and struggles between different actors and groups. The set of uneven relationships described between actors and groups is frequently used to explain change. Each approach, though in differing ways, acknowledges such references, as the following phrasing indicates

Relationships among producers and between producers and institutions

- *“ The hypothesis is that the farmers are highly risk seeking, low trust in other producers and “government”.” (complexity & common-pool resources)*
- *“The hypothesis is that long-term focus on subsidy (money and research) leads to certain type of producers who are well adapted to institutional arrangements, but food production system is less reliable and more costly.” (resilience)*
- *“How have greenhouse technology and the tomato variety co-evolved? Who are the breeders and what is the relationship between breeders and greenhouse development providers? How are the relationships between state science and private breeders and greenhouse designers changing? How has the political economy of IPM influenced the farmers' ability to use it? What is the history of the relationship between IPM companies, state institutions and chemical pesticide producers?” (political ecology)*
- *“Are answers to the questions influenced by: the production practices elsewhere (e.g., Bretagne, North Africa, Spain) ? French consumer preferences? Participation in local “collective action” institutions? Where these institutions, and what are their geographic mandates? Have these institutions actually helped a significant number of individual tomato farmers in recent times of “crisis”? What is the prospect for developing additional collective action institutions in L-R? Can collective action–whether based on new or existing institutions - modify: tomato production practices in Spain or North Africa? French consumer preferences and liability? ” (vulnerability)*

Power and regulations

- *“The key theme is the neo-liberalization of Agriculture as:*

○ *an ideological commitment to the reduction in state power relative to markets*
○ *a shift of risk and responsibility to individuals (Beck calls individuation), simultaneous with a change in regulatory regimes to favor trade*
○ *shifting accumulation regimes, typically to concentrated and large firms and to “off-shore” production sites, with cheaper labor markets and more relaxed environmental regulations”* (political ecology)

- *“The interaction between the resource user and the public infrastructure is the sanction and it is very weak. In that case* *institutions sets up a very difficult intrapersonnal dilemma for the farmer*" (complexity & common-pool resources)

3.3. The syntax of change

Based on our consideration of the different analysis of the Bemisia case study we have identified four conceptual explanatory elements that human–environment scholars use to explain change: (1) adaptation mechanisms to hazards and controls, (2) informed decisions, (3) patterns of system trajectories, and (4) power and control dynamics. In the previous section we have shown that scholars from all schools use the full set of explanatory elements of this common vocabulary. This is not to say that all scholars in the workshop share the exact same understanding of these concepts and attribute the same meaning to Adaptation, System, Power or Incentive, but the fact they all make reference to an explanatory element of change based on the fact that, for example, cognitive agents make decision (I), that a "whole" has a trajectory (S), that the dynamic of change is driven by political interactions (P), and that change occurs when the object is exposed to perturbations (A). In this section, we argue that the primary distinction between these schools of thought is how they combine the elements of this common vocabulary in their analysis: the grammatical syntax used by four schools of thought (Table 2). These choices are based on material presented in Section 3.1 and Appendix 1.

3.3.1. Resilience syntax: system trajectory and adaptation

Within resilience thinking, the central concerns and foci for explanation are mainly the relationships between the trajectory of a system, as a whole, and the adaptation of system elements and responses. Questions of structured incentives and the problem of control over system explanatory elements are considered as secondary, although not insignificant. These may be critical, moreover, in resetting the system or its parts (through an adaptive cycle, for example), but the crux of the analysis lies in the description of the systems components and its overall direction and rate of change.

3.3.2. Complexity & common-pool resources syntax: incentives and system trajectory

The work of Elinor Ostrom and other commons scholars is primarily motived by a desire to promote decision making that leads to better policy outcomes for resource users and ecosystem's sustainability (Gibson, 2005). An analytic focus on complexity & common-pool resources, therefore, stresses the importance of the relationships between economic, social and psychological incentives (rules, norms). Though these are unquestionably acknowledged to impact the adaptation and the power relations between actors, which in turn influence and direct the structuring of incentives, the essential elements of explanation lie in the varying dimensions of ecosystem sustainability that flow through structured incentives.

Table 2
The grammatical syntax used by four schools of thought.

School of thought	PISA syntax	Secondary elements
Resilience	S->A	P,I
Complexity and common-pool resources	I->S	A,P
Political ecology	P->I	S,A
Vulnerability	A->S	P,I

3.3.3. Political ecology syntax: power and incentive structure

The distinctive characteristics of political ecological descriptions and analyses of the Bemisia case study were their detailed focus on the relations between groups and actors (e.g., EU regulators, industry lobbyists, and local famers) and the structured incentives that resulted from these persistent configurations. System change and transformation, though often an important part of political ecological narrative, is usually understood as merely the outcomes of reconfigurations of the force relations and institutions, as are the specific, local adaptations of plants, farmers and consumers. As a result, systems feedbacks and individual adaptations become the product of power dynamics, though also the later preconditions for new struggles. Politics and institutions drive the cycle of adaptations and feedbacks.

3.3.4. Vulnerability syntax: adaptation and system trajectory

In this view, adaptation is the critical window through which socio-ecological systems and their elements are defined and understood. While adaptation does not "cause" the system in any specific way, it becomes the explanatory vehicle through which the system is made comprehensible and its transformation predictable. Clearly, power and incentives are important explanatory elements for explaining why specific adaptations occur and which are possible or predictable, but these fall secondary to the focus on component system explanatory elements, their capacity to withstand various impacts, and their differential vulnerability to transformation and, therefore, system reorganization (or disintegration!).

4. Using the grammar for discourses comparisons

In the field of human environment systems we are aware of one attempt to use a "grammar": Crawford and Ostrom (1995) proposed the ADICO grammar (Attributes, Deontic, aIm, Conditions, Or Else) to decode three types of institutional statements that we might observe in action arenas: rules, norms, and strategies. The three types of institutional statements are created from different combinations of the ADICO syntax: Strategies include only the attribute, aim, and a condition (AIC); norms include the attribute, deontic, aim, and condition (ADIC); and rules consist of the entire syntax. Crawford and Ostrom compare different studies that used the concept of institution, and used the ADICO grammar to analyze whether the primary focus of these authors is strategies, rules, or norms. In section 3 we described a grammar composed of four explanatory elements, each associated with one letter: Power (P), Incentives (I), System (S), and Adaptation (A). We use the acronym PISA to designate this grammar (this ordering of the letters is preferred for phonetic reasons and has no meaning in itself). In this section we comment on the usefulness of this grammar and syntax to code, compare, and identify the differences and similarities in how different human–environment approaches frame the analysis of their object of study. First, we discuss how this grammar and syntax can help resolve debates on the nature of the relations between these four approaches: we look at the resilience-vulnerability and political ecology-commons & complexity relations. Second, we discuss how this grammar and syntax can help decode other human–environment analytical frameworks and their relation to the ones discussed above. This section ends with a commentary on the potential uses of this syntax in on-going efforts to understand and transform human–environment relations.

4.1. Using the PISA syntax to examine the relations between human–environment approaches

4.1.1. Resilience and vulnerability

Some authors consider that the resilience and vulnerability approaches are mirror of one another, in the sense that resilience is the positive expression of the research objet while vulnerability is the negative expression. For Turner "*The former (vulnerability) seeks to identify the weakest parts (those most affected negatively) of coupled systems to disturbances, and the latter (resilience), the systemic characteristics that make systems more robust to disturbances*" (Turner, 2010). Miller et al. (Miller et al., 2010) state that the resilience community tends to prefer a systemic approach, whereas a vulnerability thinker tends to take an actor-oriented approach. According to these authors the types of processes and dynamics that are investigated through vulnerability are more likely to be social, political, and economic rather than biophysical and ecological. Resilience research has tended to consider the ecologically bounded scales of the ecosystem, landscape, and region while vulnerability research, in contrast, tends to consider socially defined scales of the household, community, region, and nation.

A syntactic analysis of these two approaches provides an additional perspective on that comparison and lead to different conclusions. In our view, the main difference between these schools is not on how much each prioritize attention to either social or ecological explanations, or to either negative or positive responses to disturbances. Rather, the main difference is that resilience and vulnerability approaches each articulate "system trajectory" and "adaptation" in different ways. Resilience analysis starts with an analysis of the system, its components and their interactions to understand the potential trajectories of the system. At a given stage, the past trajectory of the system indicates its possible responses to perturbations, which can be diverse and even unknown. If the general resilience of the system is high, the system will have a high adaptive capacity. On the other hand, vulnerability starts with the relationship between a particular perturbation and an object and tries to assess the response of that object. The vulnerability approach indicates the possible states resulting from this perturbation-response relationship but it will not necessarily analyze the consequences on other objects nor take into account a general trajectory of the system this object belong to. In the context of the Bemisia case study (Appendix 1), we see that resilience scholars concentrate their investigation on the slow variables (political games, bemisia-vegetation ecological relationships) that alter the "hill" between two regimes (No TYLC vs TYLC outbreak). In contrast, the vulnerability scholar concentrated his investigation on exposure, sensitivity, and-adaptive capacity of the tomato production system to various events. The second important difference between resilience and vulnerability lies in the management perspective of the two approaches (Table 1, last column). On the one hand resilience approach is linked to management interventions that seek to drive the evolution of the systems towards desirable states (e.g., pest control through predation of the vector). On the other hand, the vulnerability approach is linked to management interventions that primarily focus on reducing the consequences of perturbations (e.g., compensation after the outbreak). In brief, rather than a positive/negative or a natural/social dialectics, the difference between resilience and vulnerability schools lies more on their respective focus on the trajectory of the research object vs its reaction to a perturbation.

4.1.2. Political ecology and complexity & common-pool resources.

Comparisons of political ecology and the commons school typically stress the difference in how much each approach weighs the role of political power in shaping environmental management regimes. This dimension is often assumed to be marginal or contextual in commons scholarship, while it would be the central explanatory element of political ecology (Cote and Nightingale, 2012; Armitage, 2007; DuPuis, 2004; Turner, 2014).

Analytically, the PISA grammar sheds new light on the relation between these two schools of human–environment thought. Political ecology starts with the power & control analysis (P) to understand what sets of incentives and constraints (I) shape the decisions of actors, while complexity & common-pool resources start with the analysis of actors' decision-making. In other words, the political ecology approach to the Bemisia case focused on the relations between the ideological changes on policies and the responsibilities of the individual, whereas the commons and complexity approach focused on the farmers' decision-making process, to which the roles of policies in structuring the decision-making process was seen as secondary (see Appendix 1). The two analyses could enrich each other. In the case of Bemisia an articulation combining the political ecology and the commons & complexity approaches would lead to the following analysis. The risk regime is locked into place by interests (IPM, companies, banks, agricultural state agencies) that benefit from, and are rewarded by, the current pattern of accumulation and management. Within this context the focus is on how producers game the institutional incentives to adapt. While doing so they reinforce the risk regime they are embedded in.

In the light of our observations, we understand political ecology and commons and complexity perspectives as distinct nodes in a P->I->S syntactic axis. Turner & Robbins (Turner and Robbins, 2008) expressed a synthetic question for research on human–environment relationships which is consistent with this P->I->S syntax: "*What political and economic arrangements accelerate or decelerate reductions and enhancements in human vulnerability and ecosystem sustainability?*". The main tension between the two schools lies in the complexity & common-pool resources school's restriction to one type of arrangement (the users' self-organization) with the hypothesis that this arrangement is often the relevant option, which is consistent with the assumption that the actor's decision is the central process so individuals can realize the gains from association (Boettke and Coyne, 2005). As Armitage (Armitage, 2007) indicated political ecological interpretations would help to reveal the contextual forces (the positioning of social actors and social constructions of nature) that allow or restrict the possibility of such arrangement.

4.2. Locating new discourses in the landscape of approaches: the example of ecosystem services

The PISA grammar can also be used to analyze human–environment perspectives that are not limited to the established school of thought discussed in this paper. For instance the SETER project hosted scholars working in the field of biodiversity and ecosystem services, robustness, social representations and mental models. We analyze here how scholars representing the biodiversity and ecosystem services perspective approached the Bemisia case study. In the course of their shorter engagement with this case (compared with the longer, more in-depth engagement by the group of scholars discussed above), these workshop participants asked the following questions: "*How would possible policies for restructuring tomato production alter ecosystem services? What ecosystem services does field production of tomatoes enhance? Degrade? When production is moved to the greenhouse, what replaces field production? What are the ecosystem services (disservices) delivered by those systems?*".

For these authors, the state of the system and the services it provides are a consequence of the choices made by society.

Incentive structure is important for decisions in trade-off situations, but is not sufficient to understand systemic outcomes. In general terms, the choices favoring nature's management or conservation strategies are related to the benefits that different actors can draw and to external costs and benefits induced. They depend on perceptions of use and the services it furnishes. External costs can be not reflected in local incentives. The social value is to be set through political process leading to potential systemic outcomes. Thus the analysis of the Bemisia case by these scholars is best described as one revolving around the core explanatory elements P and S. This outcome surprised us because we were expecting that this analysis would place at its core the relationship between incentive structure (I) and systems property (S).

After codification with the PISA grammar, the resulting syntax reveals that the biodiversity and ecosystem services approach, as applied by our invited scholars to analyze the Bemisia case study, starts with the same explanatory element than the political ecology (P). These scholars sought to analyze how power and control, through policies and political process, shape the properties of the system and the services provided by the resulting ecosystem. The difference between how these scholars and the political ecologists analyzed this case in the SETER experiment is that the political ecologists' analysis of the tomato production regulation process aimed at explaining the risk-regime for the different actors, while the biodiversity and ecosystem services focused on explaining the different services provided by the various production systems (S).

4.3. Using the PISA grammar to better understand and transform human–environment relations

The PISA grammar helps better understand how different scholarly approaches link explanatory elements of change in human–environment analyses. The resulting grammatical syntax can help identify the similarities, complementarities and oppositions between different schools of thought. The use of PISA grammar provides additional perspectives to the ones found in literature. For instance it leads to (1) a better understanding of the difference between resilience & vulnerability, (2) a proposition of an approach based on the complementarities of political ecology and complexity & common pool-resources, (3) the inclusion of ecosystem services studies in the field of political ecology. These examples show that PISA grammar can be used to assess the possibility of interaction between scholars holding different flags and the orientation of this collaboration. As shown with the example of resilience and vulnerability schools which articulates the S and A in different ways, the choice of an articulation leads to different policy perspectives (see Table 1, last column).

Decoding the different discourses with PISA grammar signals areas of scientific clarifications but do not pretend to identify equivalencies. Once an agreement on a given PISA syntax is reached, different scholars can focus on the non-syntactic differences in meaning. For instance, the use of PISA grammar on Bemisia case study leads to a P->S syntax and signals that different scholars are using the Power and control explanatory element. The governance of Bemisia case studies lies more in the management of power dynamics among the different interest rather than the incentives to the producers, as one would have expected. Beside the syntactic agreement, they may have different understanding on the meaning of power, different constructions, references and frameworks: the door is open for a focused interaction among scholars to precise what the power games are, how they analyze them, and how they would try to challenge them (if they want to intervene).

The potential success of the selected management intervention depends on the relevance of the associated explanatory element. For example, when systems-thinking does not match with political jurisdictions, political units may focus instead on more locally-scaled questions of vulnerability/adaptation. And when political ecological analysis insists on a critique of power and political economy and recommends that hierarchies be challenged, powerful institutions and decision-makers are unlikely to draw on that perspective. The use of PISA grammar will not solve this type of problem but we can hope that an articulated use of different explanatory elements will have more chances to be listened and appropriated by institutions in charge of management.

5. Conclusion

Clearly there are the foundations of productive scientific communication and collaboration evidenced by the common language of SETER participants, across historically divergent (and sometimes hotly contested) schools of thought. This shared “vocabulary”, though not universal to all researchers in all schools, clearly allows better understanding between traditions. No SETER researchers were observed to fully and categorically exclude any of these explanatory elements, whether these are interactions or system effects, or the play of power between contending actors. In this sense, the glass is “half full” for building diverse research communities and devising cooperative scientific undertakings, and the conclusion of the SETER experiment lead us to encourage such exchange.

There is a temptation, under such conditions, to subsume one way of thinking within another, for example treating common property approaches as a special case of political ecology, or vice versa. This temptation is born of the apparently reasonable goal of producing a united, coherent socio-ecological theory with which to address the grand challenges of global change. This temptation is amplified by the fact that many core explanatory elements *appear* to be shared within these approaches. Having said this, the opportunities for mistranslation and disagreement are omnipresent. When the emphasis on differing explanatory elements is changed (putting either power or adaption, for example, at the center of thinking), different questions emerge from the mix.

The SETER project suggests that complex socio-ecological interactions are inevitably refracted through parallax conceptual lenses, through which the core explanatory element of the images may be the same, but their assemblage dramatically different. Attempting to reconcile these approaches through integration (Gallopín, 2006) would be precisely to undermine the core contributions of each mode of thinking. A search for “grand synthesis” therefore, may be analytically destructive.

We conclude from the SETER experiment that more effort should be mounted at cataloguing and more carefully defining the terms, explanatory assumptions, and normative implications of all socio-ecological theory, in an effort to offer some guidelines along which to sort through competing claims. Such an effort to catalogue and coherently presenting not only the intellectual vocabulary but also and mainly the grammar and syntaxes that are emerging within sustainability science is well worth the time and energy that initiatives such as SETER represent.

There is no evidence from SETER, however, to suggest that these approaches are moving in the direction of a single, comprehensive, or universal way of describing, analyzing, and predicting socio-ecological change. Indeed, it would seem the complexity of the emerging novel ecologies of the Anthropocene, as the Bemisia case underlines, may actually *propel* divergent modes of explanation, becoming the seeds of new competing accounts. Imposing a single explanatory syntax on differing research traditions would only lead to intellectual impoverishment: an effort tantamount to imposing intellectual monoculture that we can ill-afford as we seek to expand, rather than contract, our adaptive intellectual capacity in the next century.

Appendix 1. Different contributions on the analysis of Bemisia case study

This appendix presents a short version of the scholars' contribution on Bemisia case study, extracted from an oral presentation with power point files.

Bemisia & complexity & common-pool resources

If Bemisia case study is an example of possible invasive species due to climate change, we need to understand the lack of effective response at different levels of scale. What are the adapting capacities of the farmers? Farmers surviving in current high competitive market are likely to have common type of risk perception and social orientation. The suggestion is to perform survey analysis (including decision experiments) on risk attitudes and trust. The hypothesis is that the farmers are highly risk seeking, low trust in other producers and "government". The producers are able to move from one high gain high risk production system to another, especially by harvesting subsidies. The agricultural systems have evolved to go through overshoot and collapse cycles. The question is: what institutional incentives lead to this type of 'agents'?

Through this approach, two main questions are addressed:

- How to eradicate the threat of bemisia virus?
- Why is the capacity of agricultural industry so low to deal with invasive species?

The proposed method is to study spatial ecology of Bemisia building a spatial explicit simulation model at farm level to access policies and diffusion of virus among farms. This would define a model structure for future outbreaks. A series of basic information need to be collected:

- Why did farmers not get compensation? Who decided?
- What happened in other cases of invasive species?
- What are official policies on invasive species?

There are two stability domains:

- Producers who have labor intensive (subsidized) production of organic food of many different types: lower production, but more resilient.
- Producers who have capital intensive production of monocultures: high gains, but reasonable probability of collapse. This is typically effective to get governmental support to continue.

An evolutionary model could be produced, with producers with different attributes under institutional arrangements (subsidies, regulations). The hypothesis is that long-term focus on subsidy (money and research) leads to certain type of producers who are well adapted to institutional arrangements, but food production system is less reliable and more costly.

Experiments could be done. Given insights in attributes of producers, what are incentive structures to lead them practice preventive actions? The experimental problem (high gain, low probability of big negative effects) would test different incentives structures, for example conditional subsidies. (Example: Climate change experiments on policies and risk. http://www.cred.columbia.edu/)

In conclusion, Bemisia is a great example to study a number of fundamental questions on the challenges of the current agricultural system with invasive species. The focus is on producers and how they game the institutional incentives.

Bemisia and resilience

The theoretical framework of resilience focuses attention on the system's key variables, by scale and sector and how these factors interact and generate shifts between TYLC outbreaks and senescence. It also attempts to understand how alternative policies could be formulated and tried to minimize disease outbreaks. There are known management strategies for dealing with TYLC in other places e.g., in Israel TYLC tolerant varieties are grown and taller greenhouses let the heat escape. However, in France the preferred response is to suppress *Bemisia* populations using chemical pesticides.

Consideration of the issue in the context of a social–ecological system helps to reveal key components of the social and ecological subsystems as a first step toward understanding system dynamics. The key components of the system are:

- Tomato production
  - Tomato Cultivars
- Greenhouse
  - Construction
- Fuel, Labor

- Markets
- Growers and Professional Associations
- White Fly Population Dynamics
  - Nutrition/food
- Spatial Refugia
- Predators
- Biotypes
- TYLC
  - Biotypes
- Models of outbreak
- Monitoring
- Response to Outbreak

In particular we look to see how the key factors interact across levels from plants to greenhouse, region, and nation. Top-down interactions include: crop compensation, control policy, and technology/energy. Bottom up interactions include: TYLC outbreak and tomato production. Applying the panarchy model (Gunderson and Holling, 2001) one would see the top down (memory) composed of Crop compensation, Control Policy, Technology/ Energy while the revolt from the bottom up would be TYLC Outbreak, tomato production decrease. Highlights from the case study description reveal panarchies or cross-scale interactions that occur at different phases as the system shifts from one of low TYLC levels to an outbreak regime. Examples of transitions from a regime to another are presented in Fig. A1.

Research questions that follow from considering panarchies and regime shifts in the tomato-*Bemisia* outbreak system might include: a) what can be learned about the regional spread of TYLC from greenhouse to greenhouse, b) what are the mechanisms of predator control, c) how might the problem evolve under changing and uncertain conditions (e.g., climate change), and d) what can be learned from the outbreak crisis, specifically with respect to the role of compensation as subsidizing pathology or forcing adaptation. More theoretical questions would relate to managing for specific vs. general resilience (i.e., specific resilience of tomato production system to TYLC vs. general resilience of greenhouse food production to future pest outbreaks and other unforeseen events). Finally, what can be learned from the case study about tradeoffs in managing systems at the edge of stability domains?

Using the resilience framework agricultural systems are presented as being the result of a trade-off between efficiency and resilience. Agricultural systems target the efficiency and pay the price in terms of resilience.

The final questions are

Regime A	Alteration	Trigger	Regime B
No/Few TYLC	Vector-Bemesia Hosts-Vegetation	Temperature	TYLC Outbreak
No Compensation	Political power of associations	Quarantine Declaration	Compensation

Fig. A 1. Two possible transitions between regime A and regime B. In the first case, regime A is slowly altered by ecological interactions. The shift is triggreed by the high temepratures. In the second case, which was the hope of the producers, the regime A (without compensation) is altered by the political pressure. The quarantine declaration would have triggered the shift to a regime with compensation.

- Which are the epistemic communities? What are their particular roles?
- Does compensation subsidize pathology or force adaptation?
- What can be learned from interdisciplinary failures?

Next steps applying resilience framework are: development of food base, predator and regional scale spread models in addition to biophysically based population models. These would be developed as tools to integrate understanding of complex dynamics and develop possibly new ways of intervention.

Bemisia & vulnerability

The overarching research question is: what explains the vulnerabilities of the regional tomato production system associated with the climate variability/change (frequency/magnitude of heat waves/drougths); TYLC virus; tomato competition (Bretagne, North Africa, Spain) ?

The study would be done with the exposure-sensitivity-adaptive capacity frame.

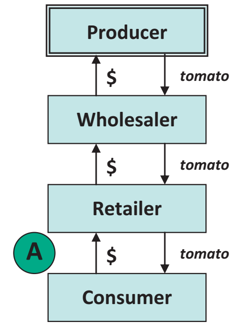

Fig. A3. The chain from producer to consumer.

The exposure is the description of the intersection of the hazard with the exposure unit. What is the climate, especially the occurrence of droughts? How many tomato producers are in the region, what is their production capacity, and where are they located, Where has the fly been found to date? Is the virus everywhere the fly has been found to date? What is the current level of market share by producers from other regions (e.g., Bretagne, North Africa, Spain) ? How has tomato production from these other regions for export to L-R recently changed?

The sensitivity is the short-term impacts/responses & conditions mediating the production of the impacts following the exposure. How much did tomato production/profits decline for regional producers in 2003? Which producers stopped growing tomatoes after 2003? What is the variation of Bemisia population relative to temperature in the field? Do regional tomato producers use a greenhouse? Produce other products? Anticipate more the decrease of tomato production? Use pesticides to target bemisia? Pledge to be "bio" report the decrease of tomato production – or TYLC – to the CPA? Are answers to the questions above influenced by: the production practices elsewhere (e.g., Bretagne, North Africa, Spain) ? French consumer preferences? Participation in local "collective action" institutions?

The adaptive capacity is current/future abilities & inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses. What do the farmers who grew tomatoes in 2003 produce today? What is the status of L-R "collective action" institutions related to tomato production? What is the function of these institutions? Where these institutions and what are their geographic mandates? What

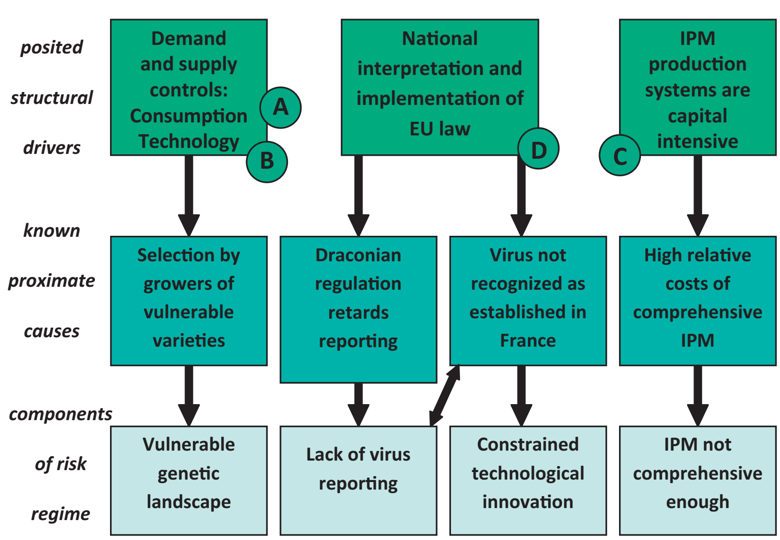

Fig. A 2. The conceptual model of Bemisia case study from political ecologists point of view.

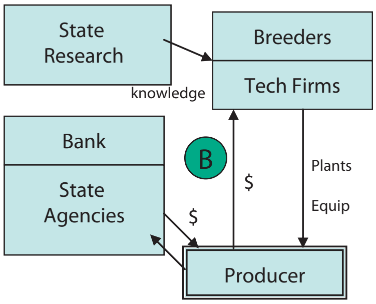

Fig. A4. The technology chain.

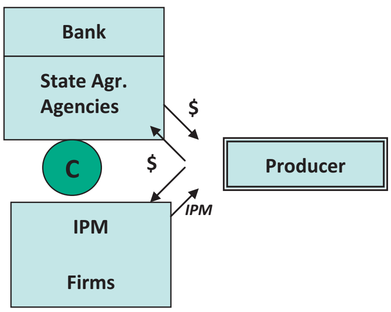

Fig. A5. The political economy of commodity chain.

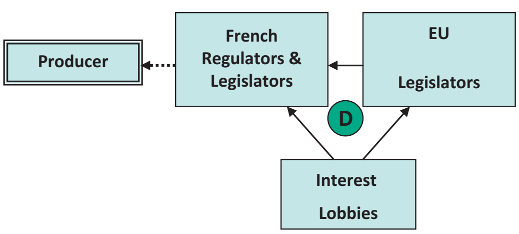

Fig. A6. The regulation organisation.

proportion of local production do these institutions represent? Are these institutions well-attended and/or well-financed? Have these institutions actually helped a significant number of individual tomato farmers in recent times of "crisis"? What is the prospect for developing additional collective action institutions in L-R? Can collective action – whether based on new or existing institutions - modify: tomato production practices in Spain or North Africa? French consumer preferences and liability? Is state compensation theoretically possible? Difficult to acquire? Significant once acquired? Are there disincentives to applying for state compensation, and if so, do these disincentives result in farmers not reporting the presence of the fly?

Bemisia and political ecology: the neoliberal production of risk and uncertain knowledges

The key theme is the neo-liberalization of agriculture as:

- an ideological commitment to the reduction in state power relative to markets
- a shift of risk and responsibility to individuals (Beck calls individuation (Beck, 1992)), simultaneous with a change in regulatory regimes to favor trade
- shifting accumulation regimes, typically to concentrated and large firms and to "off-shore" production sites, with cheaper labor markets and more relaxed environmental regulations

The conceptual model is a model of « risk regime » (Fig. A2). The current risk regime is poised for an undesirable major outbreak following a heat wave or other stochastic event. That regime is perpetuated by a few specific conditions

1. Vulnerable genetic landscape (monoculture/variety)
2. Lack of virus reporting and overall disconnection of producers from the regulatory and management regime
3. Constrained technological innovation in extension and science surrounding the virus itself
4. Absence of a multi-predator, comprehensive IPM amongst producers that might be robust enough to reduce outbreak

The risk regime persists because there is accumulation somewhere in the system. Where are the interests and how are they interested? The theoretical basis which lead to hypotheses is the agro-political economy (Kloppenburg, 1988). The risk regime is locked into place by interests that benefit from, and are rewarded by, the current pattern of accumulation and management. The value accumulates along the current commodity chain. The regulation tends to follow interests so . . . follow the money.

From the posited structural drivers four research could be developed:

A. The chain from producer to consumer (Fig. A3): Concerning the variety selection: who makes money selling these particular tomatoes? What criteria do supermarkets use in selecting varieties? How do marketers shape consumer preferences? What

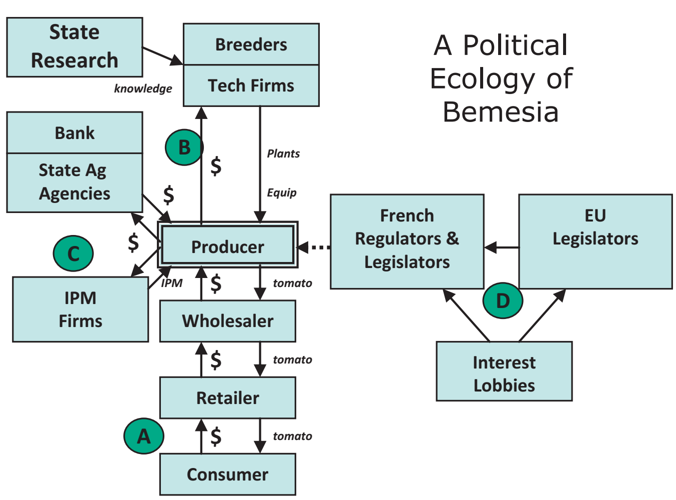

Fig. A7. The whole organisation and its flows.

were the economic and political imperatives leading to the creation of the Rougeline label and how have these influenced the choice of variety?

B. The technology chain (Fig. A4) How is the greenhouse/breed technology selected and who makes money? Where are the funds (loans, subsidies, reinvested capital) coming from to pay for investments in new technology? How have greenhouse technology and the tomato variety co-evolved? Who are the breeders and what is the relationship between breeders and greenhouse development providers? How are the relationships between state science and private breeders and greenhouse designers changing?

C. The political economy of commodity chain (Fig. A5) How has the political economy of IPM influenced the farmers ability to use it? How and when was IPM privatized? How are intellectual property rights in IPM configured and adjudicated? To what degree do IPM firms depend on public research? What is the history of the relationship between IPM companies, state institutions and chemical pesticide producers?

D. The regulation (Fig. A6) How have regulations and their implementation influenced the spread of Bemisia? What is the history of the establishment of the EU law? (actors, timing, interests, justification) How were the French regulations written and with what interpretations of EU law? What causes under-enforcement of French regulations?

The whole political ecology analysis of Bemisia is represented in (Fig. A7)

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