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Resilience, sustainability, and environmentalism

SHARACHCHANDRA LÉLÉ

Ecological Economics Unit, Institute for Social and Economic Change, P.O. Nagarabhavi, Bangalore 560 072

Resilience is turning out to be a resilient concept. First proposed way back in the 1970s in the context of ecosystem dynamics, it was then dissected and elaborated—spawning terms such as malleability, elasticity,

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hysterisis, inertia, resistance, amplitude—as ecologists struggled to make it into something measurable, usable, and distinct from its notoriously slippery predecessor 'stability'. But in the post-Brundtland era, the focus appeared to have shifted to the umbrella concepts of 'sustainability' (Brown *et al.*, 1987; Lubchenco *et al.*, 1991, Levin, 1993), 'ecosystem health' (Schaeffer *et al.*, 1988; Costanza *et al.*, 1992) or 'ecosystem integrity' (Regier, 1993; Angermeier and Karr, 1994). The article by Levin *et al.*, however, is a strong pitch for reviving the concept of resilience and even for applying it in social contexts. Why has resilience been resuscitated? How can it be operationalized? How does it relate to sustainability? And can either resilience or sustainability be considered sufficient for environmental soundness?

Resilience, 'the ability to recover from [presumably severe shocks or stress]' as the dictionary puts it, is a flag to draw attention to the need to incorporate non-linearities in models of socio-ecological systems. Superficially, it might seem surprising that it should take so much effort to get us to recognize the importance of non-linearities. After all, we experience non-linearities and irreversibilities on a daily basis: plants die of too much watering as well as too little, children falter with too little guidance but rebel at too much. Non-linearities are well-recognized in traditional philosophies and knowledge systems, be they those of Indian sages, Amazonian hunters, dialectical Marxists or even nineteenth century natural historians. Nevertheless, those branches of natural science (agriculture, fisheries, forestry, even medicine) and of social science (essentially economics) that most directly inform public policy today appear to be oblivious of such phenomena, sticking to their linear mechanistic mindsets. That such approaches continue to hold sway in face of everyday experience, traditional philosophy, and also recent developments in non-linear systems theory speaks of their hegemony over the policy-making process (Holling *et al.*, 1995; Norgaard, 1987). Any attempt to break these mindsets and hegemonies is therefore to be vigorously applauded.

Once we accept the basic thrust of the argument, however, we can proceed in the traditional manner of science, viz., developing a clear taxonomy and hypotheses. How then should resilience be defined? Here, I found Levin *et al.*'s treatment inadequate and had to take recourse to Holling (1973), who states that resilience is *the size of the stability domain* around stable time-invariant equilibria (point attractors) or stable oscillations (periodic attractors). From this definition, a number of points follow. First, resilience should not be measured in terms of the distance of the current state of the system from the edge of the stability domain, which is a constantly changing parameter. This in turn implies that reductions in the *magnitude of the excursion* away from equilibrium should not be termed as increases in resilience. Second, reductions in the *perturbing force* or in the *deviation per unit perturbing force* (the latter being the inverse of 'robustness' or 'inertia'—Westman, 1986) should not be confused with increases in resilience. They are complementary ways of ensuring the same end result (viz., system stays within the stability domain) as increasing resilience (increasing the size of the domain). Third, resilience must refer to a situation where the perturbation applied to the system is significant (to cause it to move far away from equilibrium) but *temporary* (a shock or a period of stress—Westman, 1986), because a continuously applied perturbation will eventually drive any system out of its stability domain, regardless of the size of the domain.

In the absence of sufficient resilience, i.e., if the perturbation drives the system out of a stability domain, the system may either collapse (when there is no other stable equilibrium) or may enter another stability domain, characterized by a different system structure, such as a reversed Gulf Stream. Intuitively, this seems to be the situation in which one should use the term *adaptability*: the ability of a system to keep some 'ultimate' desired state variables (say net food production) at the desired level in the face of *domain shifts* in 'underlying' ecosystems (say the agro-climatic system). Again, one can talk about the time required to adapt, the extent of recovery to the old level of the desired variable, etc. as different aspects of adaptability. But it is clearly useful to distinguish adaptability from resilience. For instance, an agricultural system may be resilient to (able to recover from) occasional severe droughts, but it may not be able to adapt to a shift to a significantly drier climatic regime.

Using the above framework, one can begin to evaluate various hypotheses about the resilience of socio-ecological systems tossed out by Levin *et al.*, and propose a few others. First, if the perturbation is anthropogenic (such as net CO_2 emissions) and clearly of significant magnitude, then, regardless of the exact nature of the system and one's distance from equilibrium or the edge of the stability domain, reducing the perturbing force (stopping the burning of fossil fuels) is clearly one (and probably the best) means of reducing the chances of a disastrous domain shift (say in the climate system), even though this does not really constitute an increase in system resilience. And a careful distinction between resilience and adaptability would, for instance, prevent the climate change debate being hijacked by the adaptationists.

Second, a key result of resilience research (mentioned in passing by Levin *et al.*) is that one should attempt to work with natural variations. Small perturbations should be utilized to build resilience rather than be suppressed in order to reduce variability of the state variable. For instance, it is better to leave mild illnesses untreated so as to build immunity rather than ingest antibiotics at the mildest sneeze. It follows that Levin *et al.*'s general statement that 'effective feedback is necessary for resilience' needs to be qualified, because taking medicines at the mildest sneeze is in fact a sign of a system with a very effective negative feedback! Normal negative feedbacks reduce short-term variability, what resilience needs is a non-linear negative feedback: nil at low values of deviation and high at values close to the edge of the stability domain.

Third, competition—and the *positive* feedback it provides—may lead to greater efficiency, but it is not necessary for resilience: most traditional resource management systems, now seen as being resilient and ecologically well-adapted (Berkes *et al.*, 1994), have evolved in non-competitive communitarian settings. Fourth, the link between risk-spreading and resilience is complex. If risk is adaptively internalized, by say a person developing multiple skills, the results are different than if it is externalized, by the person continuing to specialize but hooking up with a much larger system: the regional or national job market. The latter approach increases the connectance of the overall system. It has been shown in a number of cases, ranging from food webs (May, 1973; Siljak, 1978, who worked on 'connective stability') to trade networks (Siljak, 1978), electrical systems (Fink, 1991), and (qualitatively) even stock markets (Rochlin, 1991), that indiscriminately increasing connectance may increase efficiency and even asymptotic stability, but it reduces resilience to structural perturbations in the system. Furthermore, 'dynamical systems composed of interconnected subsystems are stable [with respect to disruptions in connectance] if the subsystems are self-contained and the interdependence between the subsystems is properly limited' (Siljak, 1978, p. 2): something for us to ponder over in this era of indiscriminate globalization, free trade, and networking.

Fifth, resilience may in fact require some 'slack capacity' (Rochlin, 1997) that is relatively 'unplugged' from the larger system (such as a stash of gold jewellery at home as against simply a diversification of one's stock-market investment portfolios), so that this capacity is unaffected by shocks in the larger system. 'Exploiting all opportunities for mutual gain' (Levin *et al.*) may in fact reduce resilience by leaving no such 'slack'. On the other hand, adaptability may require a different kind of slack: a store of as yet unexplored, unvalued resources (such as biodiversity), and of course the ability to learn.

Clearly, since resilience and adaptability are defined with respect to a stability domain, the notions of equilibrium and stability continue to be relevant even after incorporating non-linearity. In general, for a system to be able to persist (in some desired form or with some desired properties) over time, i.e., to *sustain*, requires that it be at or around some equilibrium, have some stability in the face of small ('normal') perturbations, some resilience in the face of large ('abnormal') perturbations, and some adaptability to domain shifts. Thus, rather than stretch and pull the concept of resilience (sometimes beyond all recognition) or cast the debate in terms of short-term stability versus long-term resilience, it would be more appropriate to think of these properties as different attributes of *sustainability*—a concept general enough to serve in most discourses as one of society's meta-objectives (Lélé, 1988, 1993).

Particular situations would require more emphasis on particular attributes: systems characterized by high degrees of environmental variability (such as semi-arid regions or turbulent business conditions) must give primacy to resilience (hence the domination of *r*-selected grasses or small, loosely structured, opportunistic firms), while those characterized by low environmental variability (such as moist tropical regions or stable economies) permit the neglect of resilience (hence the domination of *k*-selected trees and complex rain forests or large, complex firms). Each specialization comes at the cost of some other qualities, and has an associated productivity gain under certain conditions. Research may no doubt have hitherto focussed disproportionately on stable ecosystems. But to insist that resilience is somehow more 'fundamental' would be akin to insisting that *k*-selected species are unfit to survive.

Finally, it needs to be pointed out that the critique of conventional socio-environmental science is much broader than just the problem of not incorporating non-linearities. From a scientific perspective, the study of complex socio-ecological systems also suffers from the problem of reductionism—the tendency to look at tree growth only as a function of age rather than thinking of succession, disease and pollination in modelling forest stands (Holling *et al.*, 1995)—and the lack of methodological pluralism (Norgaard, 1989).

From a social perspective, conventional, primarily Western, environmental science is also characterized by narrow value systems. Both resilience as a goal in itself and sustainability as an overarching goal essentially pertain to the *temporal* dimension of human well-being. There is, however, also a simultaneously or primarily *spatial* dimension to many environmental problems, where current actions of one group affect the current well-being of another group. Typically, these spatial externalities (and the political power of the involved actors) are asymmetrical, if not entirely unidirectional. Unless one takes a clear position that in addition to our concern for the future, *intra-generational justice* is also a fundamental value, these environmental problems will get short shrift. For instance, when upstream factories pollute rivers that are the primary source of drinking water for downstream communities, the argument that the pollution is reducing 'long-term river ecosystem resilience' or 'water use sustainability' will not cut much ice with the factory owners: one has to invoke the notion of intra-generational justice. Similarly, a concern for the climate we may pass on to our future generations will not *in itself* prevent unfair arm-twisting by the North. The North would prefer to increase the resilience of the global climate system by buying up forest lands and emission rights from the South at historically biased exchange rates, rather than reduce its own level of fossil fuel consumption. The lessons from the history of environmental policy are unambiguous: no amount of 'trust', 'clever institutional design' (a la the already faltering Montreal Protocol), or 'epistemic consensus' (a la the IPCC: but see Jasanoff, 1992) can compensate for major asymmetries in the interests and powers of the different actors. And no amount of concern for long-term resilience of the human ecosystem can by itself ensure a fair environmentalism or a just development. Levin *et al.* do not claim that it does, but in a world of limited attention spans and paltry environmental budgets, we must ensure that resilience does not knock more pressing but politically inconvenient matters off the agenda.

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