Complex Systems Dynamics: Implications for Sustainability, conception and policy

Thomas Brinsmead and Cliff Hooker

This chapter explores the implications of a complex dynamic systems perspective for the adequate conception of sustainability and satisfactory sustainability policy. The rigorous representation and precise analysis of a much richer class of dynamical systems than previously – in particular nonlinear aperiodic dynamical models, in addition to linear correlational, linear dynamical, and nonlinear stable equilibrium and periodic models - has had a significant influence on the formal management of appropriate human interaction with the natural world, which is the essence of sustainability policy.

In broad terms, the general aim of sustainability policy is to ensure that environmental processes that are valued, whether on ecological or more pragmatic grounds, are preserved and/or enhanced over time throughout the process of continual human interaction with environmental processes. Because of multiple causal interactions among human and environmental subsystems, sustainability policy (and its antecedents) has always required organisational mechanisms for collectively co-ordinated action. However earlier formal approaches to "environmental management" were based on cause-and-effect models that in retrospect can be recognised as a narrowly limited class, though nevertheless previously very successful in supporting significant advancements in components of human wellbeing. This chapter briefly reviews limitations of using dynamical models belonging to these earlier limited classes - including those that are restricted to being linear proportional, unidirectional causation, close to stable equilibria, homogenously constituted, and/or completely deterministic - in the light of appreciation of the ubiquity of other, more complex, dynamical behaviours in natural and human systems.

Important enhancements to sustainability conception and policy arise from greater appreciation of the significance of dynamical behavioural complexity (that cannot be obviously simplified by, for example, statistical treatment) due to networked non-linear interactions among many dynamical components. First, the hitherto dominant conceptions of sustainability – i) remove negative environmental impacts and ii) maximise human + natural capital - are challenged by a radically different approach: iii) sustainability as maintenance or enhancement of adaptive resilience, the capacity to robustly preserve continued functioning through short term perturbations and long term change. This third concept is arguably more fundamental than the others because (a) it prescribes sustaining what is essential to continued system existence in a world of evolution-development, (b) leads to better outcomes than the impact approach because it recognizes long term dynamical interaction between human and environmental processes and thereby offers synergies between sustaining ecology and economy and is more practical than the capital notion because it avoids trying to predict the long term future, and (c) is their natural successor in policy strategy because it alone incorporates fundamental uncertainty into capital's dynamical models and decision strategies.

Second, such behavioural complexity consequently leads to significant limitations on the practical feasibility of precise prediction (even where precise, local causal explanation could be provided by retrospective dynamical analysis). Prediction limitation has the significant consequence that sustainability policy becomes a problem of risk management under uncertainty rather than deterministic optimisation. It also implies that management for sustainability should be an adaptively contingent interactive feedback process, directed to enhancing the resilient achievement of some acceptable condition in the face of ignorance, rather than resulting in unconditional commitment to specific action. This consideration, in addition to the observation that path dependence is ubiquitous, for example because important global dynamical constraints often have their origin in the amplification of apparently small past fluctuations, points towards backcasting as a promising framework for sustainability policy.

Prediction limitations also suggest that responsible sustainability policy will be a co-evolutionary learning process, not only at tactical scales among intention, prediction and action, but also at strategic scales between theory and observation, and between values and descriptive understanding. Inherent limitations on dynamical modelling, prediction and normative development imply that a portfolio of precautionary do-a-little-to-learn activities is as important a component of sustainability strategy as is activity directly maintaining substantively valued conditions and processes. The dynamics of these learning processes are also characterised by path-dependent sensitivity to initial conditions. More subtly, limitations on state prediction precision suggest that sustainability policy acceptability conditions should be framed in terms of broad constraints on dynamically relevant system organisation, rather than precise specific targets for subsystem states.

Furthermore, achieving the adequate management of risk implies a requirement for a robust appreciation of the significance of values implicit in both learning, and other, methodological norms, in addition to the traditionally recognised significance of values in determination of substantive policy goals. The explicit appreciation of relevant values assists in constructing appropriately simplified representations of the relevant dynamics of a given problem situation, which is a significant subproblem within sustainability policy, and backcasting in particular.