Ecological Economics: a workbook

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What Does an Ecological Economist Do?

An ecological economist solves problems. Serious problems at the interface of human systems and the global ecosystem that sustains us. Problems that are complex, in which all parts within the system under study are connected – one twitch affecting the next, and the next, and the next, and potentially feeding back on the original twitch.

Problems that are not suitable for experimentation or repeatable scientific observation. Many environmental problems have a sample size of one: a single unique ecosystem or, at the most extreme, a single planetary system. We can make observations or perform experiments on a smaller scale, but complexity means that understanding things on one scale does not necessarily translate to understanding on a larger (or smaller) scale. Nor is it possible to make numerous observations of the same system over time. The interconnected nature of the global ecosystem and global economy means that systems are in a constant state of change. In a continually co-evolving system, observations at different times are based on different conditions.

Problems where there is rarely adequate baseline data, and even current data and ‘facts’ are scarce and uncertain. The interconnected nature of complex systems implies a constant state of change, where every observation is based on different conditions. Even if experimentation were possible, tinkering with human systems or unique ecosystems presents serious ethical problems. As a result we can neither get sufficient observations for statistical analysis, nor can we use a scientific ‘control’. Even if ethical experimentation were possible, uncertainty and ignorance in complex systems is often irreducible – it is a property of the system itself, and not simply of incomplete knowledge or characterized by risk.

Problems where there is rarely one right answer. What one stakeholder considers an appropriate solution depends very much on that individual’s subjective values – including attitudes towards risk or obligations to future generations. Even the decision of what to study and the description of the problem itself depend on values.
Problems where the stakes are high, and decisions often need to be made right away. How we treat the environment matters profoundly for this and future generations, and delaying a decision while we accumulate more information is itself a decision, which in many cases will lead to irreversible outcomes.

What steps does the ecological economist take to solve problems in the face of complexity – without the ability to experiment and test, in systems where uncertainty and ignorance are the norm, when there are no ‘right’ answers, and the stakes are high and decisions urgent? How can students help solve a problem, and learn ecological economics at the same time? And ultimately, how can we shape the world into one that is environmentally sustainable, socially just, and economically efficient?

These are the challenges of the workbook.

**BOX 1-1: Complexity**

Complex means a lot more than complicated. Complex systems are characterized by positive and negative feedback loops, highly non-linear change, emergent phenomena, surprise, and chaotic behavior. What does this mean? Positive feedback loops increase the impact of some action. For example, global warming may thaw the arctic tundra, releasing methane, which is a powerful greenhouse gas. This will lead to more global warming, more thawing of the tundra, and more methane emissions: a positive feedback loop. Alternatively, increased atmospheric CO₂ contributes to global warming, but a warmer average climate with high CO₂ may accelerate plant growth, increasing the rate of CO₂ sequestration in a negative feedback loop. Feedback loops lead to non-linear change: we should not expect a linear increase in atmospheric CO₂ concentrations resulting from greater anthropogenic CO₂ emissions, nor a linear increase in temperature owing to greater CO₂ concentrations, nor linear change in the ecological and economics impacts of climate change.

Emergent phenomena are global behaviors that cannot be understood on the basis of the rules of the underlying interactions. For example, consciousness emerges from the interaction of neurons, but cannot be understood solely on the basis of the rules guiding the behavior of neurons. Many ecosystem functions are emergent phenomena, and human impacts on these ecosystems may therefore cause unpredictable surprises. A related source of surprise is the fact that complex systems may hover around attractors, a more or less equilibrium state to which a system returns even after large shocks. However, a sufficiently large shock may send a system towards another attractor, which may be a dramatically different but similarly stable state. Finally, chaotic behaviors are those in which even infinitesimal variations in initial conditions lead to entirely different outcomes. Thus, an immeasurably small difference in initial conditions may lead a system to fall into one attractor basin rather than another as the result of human impacts.
Figure 1.1 Negative feedback loops

The basic point in such systems is that the whole is greater than the sum of the parts. When dramatic change will occur cannot be predicted, nor can the state into which a system will change. Evolution is a complex behavior, and ecological economic systems co-evolve. In such systems, cause and effect is neither deterministic nor linear. A reductionist, analytical approach of breaking a problem down into ever-smaller pieces alone will not help us to understand it. We must instead take a systems approach, described in more detail throughout the workbook.

A TRANSDISCIPLINE FOR AN AGE OF POST-NORMAL SCIENCE

In the traditional view of scientific inquiry, science is seen as a value-free puzzle-solving exercise based on careful observations and repeatable experiments. Scientists try to understand nature through observation and measurement. As observations accumulate, the scientist develops a hypothesis that explains what has been observed, and uses the hypothesis to make predictions about what might occur. These hypotheses are then tested by
experiments or further observations. If the hypothesis is shown to be wrong (falsified) then the scientist develops another hypothesis that explains the discrepancies between observations and the previous hypothesis. When a hypothesis is found that consistently explains predictions, it becomes a theory, at least until new observations falsify the theory, and the process continues. This circular, trial-and-error approach constantly tests the degree to which theories presented explain reality.

However, the issues above of complexity, repeatability, uncertainty, subjectivity, and urgency are significant barriers to normal science. In response to such challenges, a new approach to science has been labeled post-normal science. This lens of inquiry suggests four important modifications to traditional science.

First, post-normal science challenges us to extend our notion of who is capable of making decisions, including representatives beyond just scientists and credentialed experts. This approach emphasizes diverse values and expertise of stakeholders who may have intimate contact with a specific system, and observations and gut instincts not limited by disciplinary blinders.

In the university there are disciplines, but in the real world there are problems. Most of these problems are so complex that no single discipline is equipped to resolve them. Ecological economists must transcend artificial disciplinary and institutional boundaries. Decision makers drawn from a broader pool are more likely to think ‘outside the box’, and come up with innovative solutions. And even if a traditional expert-based approach were to arrive at the same policy advice as an extended peer community, in the latter case the decision may be much easier to implement simply because stakeholders were an integral part of the process.

Second, post-normal science also challenges us to ask what kind of information is acceptable for the decision making process. Acceptable information should reflect the expertise of the decision makers, as well as the uncertainty of scientific ‘facts’. Folk wisdom, local knowledge, anecdotal evidence, investigative journalism and small-scale surveys can have a place alongside expert opinion, scientific evidence, and peer-reviewed reports.

Third, post-normal science forces us to ask how much information is required to make a decision. There are considerable costs to acquiring additional information, the most important of which is the possibility of irreversible changes that could occur while we are acquiring it. Forced to make decisions in the face of uncertainty and ignorance, we should rely on the precautionary

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principle. That is, we should avoid decisions that risk catastrophic and or irreversible outcomes, even when we perceive the risk of such outcomes to be low. Rather than trying to maximize probable net benefits, for example, it may instead be better to minimize maximum regrets.

Fourth, post-normal science rethinks how to assess the quality of a decision. The quality of research in complex ecological-economic systems simply cannot be judged solely on the basis of ‘hard’ scientific criteria such as replicability, analytical rigor, and peer review. Instead, its quality must be determined by an open debate among those interested in the outcome. Verdicts from such a group carry “moral force and hence political influence.”

Thus, a post-normal lens to problem solving emphasizes the central role of stakeholders in decision-making, knowledge generation, and extended peer-review. The role of stakeholders, together with the complexity of problems in the realm of the ecological economist’s purview, further demands a transdisciplinary orientation to problem solving. As taught in many universities, traditional disciplines expose students to a set of tools they are expected to apply to any problem. If the disciplinary toolset is inappropriate for a particular problem, the researcher is expected to choose a different problem.

We do not typically have that luxury outside academia. Thus, ecological economics takes an alternative approach, in which there is no one specific set of methodologies. Instead, ecological economics defines a broad area of interest in which problems abound. The researcher selects a problem of interest, and this problem then determines the tools needed to resolve it. The necessary tools, methodologies, and insights for resolving the problem can be drawn from any discipline. “Multi” is many, “inter” is between, and “trans” is across. By incorporating knowledge across disciplines, very often the combination of tools and ideas lead to new tools and ideas, and transdisciplinary knowledge and understanding is born!

**BOX 1-2: The Problem of Global Climate Change**

For our first problem, let’s start big! Consider the problem of global climate change. Many economists studying climate change as an economic problem have taken the stance that better information and characterization of risks are required before significant reductions in greenhouse gases should commence. By characterizing the economic costs and benefits of greenhouse gas mitigation, the economics approach considers only those damages to the economy from a changing climate that can be assigned a probability. With probability and cost estimates in

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2 [http://www.jvds.nl/pns/pns.htm](http://www.jvds.nl/pns/pns.htm)
hand, the climate change problem is reduced to a question of maximizing net present value (i.e. benefits less costs over time, discounted to today’s dollars, see Chapter 10, pp. 181-182).

A major shortcoming to this approach is ignoring uncertainty and ignorance. What about the potential outcomes that cannot be assigned a probability? What about the potential outcomes that cannot even be imagined? Extensive study of the paleoclimate record suggests that we should not expect climate change to be smooth, gradual, and perfectly predictable. Past climate change has in general been characterized by surprises in the form of sudden, unexpected shifts between alternative patterns of atmosphere and ocean circulation, leading to rapid changes in regional and global climates. Since a stable, predictable climate has no substitute, and climate change is likely irreversible, should policy makers instead take advice that errs on the side of caution? In fact, the incorporation of “surprise” into standard economic models of climate change results in significantly higher “optimal” greenhouse gas control rates.

Uncertainty presents a significant challenge to policy makers who must move beyond a limited notion of marginal change, and incorporate

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a broader sense of **option value** – literally the value of having an option to do (or avoid) something in the future. When change is irreversible, firms, households, and societies alike will build option values into their decision rules. Applied to climate change, the value of avoiding an irreversibly bad climate scenario in the future has a large option value today. Using economic logic alone, the option value of avoiding an irreversibly harmful situation should be added as a benefit in the cost-benefit calculus when considering investment in greenhouse gas mitigation. The same logic holds for deforestation, acid rain, biodiversity loss, and most other environmental problems.

### THE PROBLEM WITH LEARNING, AND PROBLEM-BASED LEARNING

Transdisciplinary problem solving poses an interesting learning challenge. No one is likely to become proficient in all disciplines or incorporate all stakeholder perspectives. Yet we’re making the case that to solve problems requires knowledge across disciplines and broad participation from stakeholders. This requires no less than a new way of learning.

The tradition through primary, secondary, and higher education has been a mold of specialized, disciplinary, sequential learning isolated from the messy world of uncertainty and dynamic change. Yet the challenges facing this century’s graduating classes are inherently multi-dimensional, cross-disciplinary, and interdependent. As an integral part of the sustaining and containing global ecosystem, the economic system cannot be understood in isolation from the Whole – we can’t erect neat disciplinary boundaries around this inherently complex field of study. Nor is it feasible to teach students how all the elements of the system work—a lifetime of education would not be enough. The most you can hope to learn is a process for problem-solving. But this is hard to figure out in the abstract. We at any rate cannot conceive of an effective way to teach transdisciplinary problem solving that doesn’t focus on real problems.

Furthermore, traditional lecture based courses are simply not very efficient ways to learn. What do you recall from a class in which the instructor lectured and your performance was evaluated on how well you could memorize and regurgitate each lecture? Does an accountant learn accounting in a classroom, or by doing it? Does a lawyer learn law in a classroom, or by doing it? A

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doctor? An engineer? A policy-maker? In fact, although each of us have PhDs in economics, none of the authors of this book actually learned economics in our undergraduate or graduate classes. We were ‘exposed’ to economics in class, but we truly learned and retained knowledge of economics when we first had to teach or apply economics. Ecological economists must learn through practice every bit as much as a musician or athlete. Why wait to learn until you get out of school?

Believe it or not, this is not a mystery to our brethren in higher education. The learning pyramid illustrated in the Figure 1.3 is well-known, tested, and understood. It is one of those unspoken truths that professors and universities are at fault for ignoring. Lectures may now be powerpoint slides at lightening speed, but they are still lectures. Video-clips, live demonstrations, lab work, discussion groups, etc. are all used in the classroom, but most often as supplements to lectures. The social sciences and humanities (and in general, liberal arts education) are perhaps most at fault for abusing the lecture format. The more progressive medical, engineering, and business programs have long recognized the power of learning by doing, and have pioneered case-based learning.

Ecological economics builds on the case-based tradition of education with some new twists. The term we like to use is problem-based learning. In many courses, professors design problems to study or pretend to work on in a case-based format – a time-consuming process with little to no benefit to those most affected by a problem. In ecological economics, we believe that there are enough real life problems that there is no need to spend time designing new ones. And these problems can use all the help they can get . . . as soon as possible. Even as students, you can play an important role in solving real problems. In your first attempts at problem solving, you may make mistakes. You may fail. But it is often just as important to know what fails as what succeeds, and of course to learn from our mistakes.

We use numerous examples in this workbook of student projects that have played an important role in solving a problem. In some of these examples, if the student group had not been there to work on the problem, it would have been too late to do anything. However, these examples are provided just to help get the creative juices flowing. You’ll get the most out of a problem-based learning approach to ecological economics if you are working on your own problem, and that is exactly what the rest of the workbook is designed to help you do!
The problem solving process:

1. Build the Problem Base
2. Analysis
3. Synthesis
4. Communication

Table 1.1 outlines the problem solving steps, focal questions, and project milestones along this journey, organized into the main tasks of building the problem base, analyzing the problem, synthesizing the findings, and communicating the results. Building the problem base includes choosing, defining, and structuring an ecological economic problem. Analysis is the breaking down of your problem into understandable components. Synthesis is the re-integration of the parts in a way that helps us better understand the whole. Communication is the translation of results into a form relevant to stakeholders, broadly defined as the extended peer community.

Figure 1.3 The Learning Pyramid.

PROBLEM SOLVING AND SYSTEMS THINKING

This workbook is designed to help guide research, stimulate ideas, and share examples of transdisciplinary learning. Table 1.1 outlines the problem solving steps, focal questions, and project milestones along this journey, organized into the main tasks of building the problem base, analyzing the problem, synthesizing the findings, and communicating the results. Building the problem base includes choosing, defining, and structuring an ecological economic problem. Analysis is the breaking down of your problem into understandable components. Synthesis is the re-integration of the parts in a way that helps us better understand the whole. Communication is the translation of results into a form relevant to stakeholders, broadly defined as the extended peer community.
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<td>What are the desirable ends?</td>
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<td><strong>ANALYSIS</strong></td>
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<td>Where can these knowledge and skills be found among stakeholder expertise?</td>
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<td></td>
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<td><strong>SYNTHESIS</strong></td>
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<td>Bringing it all together.</td>
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<td>What are the key positive and negative feedback loops in the system?</td>
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<td>What ends get priority and to what extent should resources be reallocated to achieve them?</td>
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<td><strong>COMMUNICATION</strong></td>
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<td>Communicating results.</td>
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<td>How can your work help change the world?</td>
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<td>How can your project inform policy and management reform?</td>
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The workbook is similarly organized into these four parts, however, recognizing from the outset that problem-solving is rarely a linear, sequential process. If you follow these steps and find the process to be as easy as 1-2-3, then you’re either a truly gifted problem-solver, or you’ve only scratched the surface of your problem of study. Problem-solving isn’t easy. If it were, there wouldn’t be so many problems to solve! Most projects will visit, and re-visit, again and again the steps in the process. Most projects will find more dead-ends than open alleys. Most projects will be messy and at times frustrating. But if you stick with it, most projects will be both personally and socially rewarding.

Given this fair warning, it’s essential to maintain a **systems perspective** throughout the problem-solving process. As we’ve started to describe, complex systems are, well, complex. They are loaded with positive and negative feedbacks. Understanding their intricate and evolving balance and how they contribute to properties of an underlying system of study brings us one step closer to knowing how, where, and when to intervene in a system. Analogous to holistic medicine, a healer doesn’t simply treat the symptoms of the disease but searches for a cure by evaluating the entire person – lifestyle, habits, diet, and so on. In ecological economics, simple technological fixes to problems (the equivalent of surgery in modern medicine) are rare. More often than not, if an effective technical solution to a problem exists, then the real problem is: why has that solution not been implemented? Often, closer inspection reveals that the technical fixes, like surgery, are often not real solutions in the first place. Heart surgery on an overweight smoker does not solve the underlying problem, nor do hydrogen powered ‘hyper-cars’ in a world where the number of cars and the miles driven per year exhibit exponential growth.

Solving problems is nothing more than making the appropriate interventions at the appropriate places, at the appropriate times. Donella Meadows, lead author of the well-known *Limits to Growth* report to the Club of Rome’s Project on the Predicament of Mankind, was one of the great systems thinkers of our age. Her life’s work on systems modeling and education lead to deep insight into leverage points – those places in a system where a small shift in one thing can lead to large changes in everything else. The vast majority of private and public policy attempts to leverage a system with what Meadow’s categorizes as the “numbers” – taxes, subsidies, and standards – yet this is typically the least effective place to intervene in a system and change its course. Each year’s

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local, state, or federal budget debate has become the dominant place to seek change in the system. But this is only playing with the numbers in a system that is plumbed the wrong way, or with antiquated rules, or long forgotten goals, or a failed mindset worshipped by unquestioning parishioners. Fixing the plumbing – the material stocks and flows, the positive and negative feedbacks, the information exchanged between system components – has higher leverage than playing with the numbers. Changing the rules (the incentives, punishments, and constraints) has higher leverage still. Changing the goals of the system still higher. And what Meadow’s finds as the most effective place to intervene in a system is its mindset or paradigm—its **pre-analytic vision**— from which the goals, rules, and feedback structure arises.

A systems perspective, or systems thinking, is implicit throughout the textbook. When you begin to apply ecological economics to solving problems systems thinking must be front and center. Without actively, consciously, and conscientiously taking a systems perspective, you run the risk of adopting a ‘solution’ that causes other even bigger problems. Throughout the workbook, we are more explicit about the importance and uses of systems thinking to minimize this risk.

It’s also essential to contact a **sponsor** – an individual or organization already working to solve a problem in which you are interested – early in the process. It’s very rare that a problem is solved during the course of a semester, or even an academic year. There are times however when real life decisions have to be made in a very short time, and a semester may be all the time available to gather, analyze, synthesize and communicate the information necessary to make a good decision. Whether you are contributing to a project that will continue long after you move on, or you are racing to complete your project before an imminent deadline, a sponsor brings continuity and accountability to your work.

A sponsor might be a local institution from the not-for-profit sector, a government department, a local teacher or school, a for-profit business concerned with social or environmental issues, or your professor. Sponsors can save you an enormous amount of time in defining your problem, provide essential background materials, direct you towards the aspects of the problem where your research will be most useful, show you how to deliver your results in an appropriate format, and offer the continuity and structure to make sure your research is actually put to use.

By following a problem solving process, maintaining a systems perspective, and working with a sponsor, your work can make a real contribution, however small, towards solving a problem that concerns you personally. Whatever you accomplish, no research you undertake will do any good unless you communicate your

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The **pre-analytic vision** in ecological economics starts with an image of the economy with the containing and sustaining ecosystem. *See Ch. 2 in the textbook.*

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Working with a **sponsor**.
The three keys to success in problem solving: communication, communication, communication.

results to someone who can act on them. Without effective communication, your research is useless. Period. It's been said, “We are drowning in information, yet starving for wisdom.” In analysis, academia has perhaps earned a grade of B+. There is little doubt that the ivory tower has generated volumes and volumes of information through analysis of the parts. In synthesis, we’re closer to a D. The sciences have just scratched the surface of synthesis, but the social sciences and humanities are woefully behind. But in communication, we deserve no better than an F.

The biggest hurdle to effective communication of research to the general public has been an age-old hang-up called “objective distance”. Many academics excel at generating information, only to be presented to their peers or sit on library shelves in obscure journals, theses, and dissertations. Books are published and sold to these same libraries to be sourced and cited by other academics. Knowledge advances, but wisdom is evaded. Research at times informs policy, but the researcher almost always keeps their objective distance, assuring (even striving) not to get involved in advocating or implementing solutions.

The practice of ecological economics has identified a critical leverage point to problem-solving by shortening this objective distance via effective and timely communication. Jane Lubchenco in her presidential address to the American Association for the Advancement of Science (a highly respected professional society for science) stressed the critical importance of communication from the scientific enterprise in the “century of the environment” in what she calls a “new social contract for science”:

The new and unmet needs of society include more comprehensive information, understanding, and technologies for society to move toward a more sustainable biosphere – one which is ecologically sound, economically feasible, and socially just. New fundamental research, faster and more effective transmission of new and existing knowledge to policy-and decision-makers, and better communication of this knowledge to the public will all be required to meet this challenge.9

This is the challenge put forth to the ecological economist. Let’s get on with it!

The call for a post-normal science has been answered to a large extent by the tradition of systems thinking. Similar to traditional science, systems thinkers break problems down into their component parts. However, more like post-normal science, a systems approach focuses on the interactions of these parts in an effort to achieve a greater understanding of how the whole functions. The systems thinker asks:

- Does a change in a system component lead to a change in other components?
- Do those changes feed back into additional changes in the first component?
- Do those feedbacks reinforce the first change (positive feedback), or dampen it (negative feedback)?

For example, when dairy farmers in Brazil’s Atlantic Forest cut down trees, the moisture-laden water blowing in from the ocean no longer condenses on the now cleared forest, reducing the amount of water in the system. The canopy no longer forms an insulating layer that retains humidity and reduces temperature extremes. Flammable grasses grow where the forest once stood. The grasses burn, damaging and eventually destroying the remaining forests. Tree seeds cannot germinate on the dry soils in the dry air. Eventually, the forest may disappear altogether through a self-reinforcing, positive feedback loop. By focusing on the nature of feedback loops and understanding the other properties of complex systems, system thinkers take a holistic approach, complementing more reductionistic analysis.