

Nature's Matrix

LINKING AGRICULTURE, CONSERVATION
AND FOOD SOVEREIGNTY



IVETTE PERFECTO, JOHN VANDERMEER
AND ANGUS WRIGHT

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Linking Agriculture, Conservation and Food Sovereignty

Ivette Perfecto,
John Vandermeer
and
Angus Wright

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Preface

The burrowing bettong, the golden bandicoot and the desert bandicoot are all extinct. They were desert mammals from Australia that depended on a patchwork of habitats created by fires that were set purposefully by Aboriginal Australians as part of their ecosystem management strategies. The European Australians ended this fire management system when they set up reserves and forced the native Australians to move into settlements, thus ending the traditional and sophisticated system of fire control and causing the extinction of a bettong and two bandicoots. What ‘caused’ these extinctions? They were caused directly by the change in fire regimes, but, more importantly, they were indirectly caused by ignorance of the way the ecosystem worked and the role of Aboriginal management, combined with an arrogant belief that the European system of knowledge was unassailable. Ignorance and arrogance, we argue, are likewise major forces in the current biodiversity crisis: ignorance of fundamental ecosystem processes and the role of humans in them, and an arrogance asserting that current dominant political ideologies are universal and sacrosanct.

This text is based on our repeated observations of three key issues that seem to become more important as time passes. The three are intimately related to one another, yet have been mainly treated as isolated issues by academics, conservation managers and in the popular media. The first is the crisis of biodiversity loss, universally acknowledged as a major contemporary problem. The second has to do with food and agriculture, a crisis issue for the past two decades. The third is the political unrest in rural areas of the Global South, engendered most recently by collapse in rural product markets and resulting in massive rural–urban migration as well as international migration. This book contains an argument of how these three issues are interrelated in complex ways, focusing on the need to understand that interrelationship for the generation of effective conservation programmes, while at the same time recognizing the global need for agricultural production.

Our analysis stems from the current (and probably future) nature of tropical landscapes as being mainly fragments of natural habitat surrounded by a ‘sea’ of agriculture. Recent ecological theory shows that the nature of those fragments is not nearly as important for conservation as the nature of the matrix of agriculture and other management systems that surrounds them. Ecological science has come to understand that local extinctions from those fragments are inevitable and must be balanced by

migrations if regional or global extinction is to be avoided. High migration rates occur in what we refer to as 'high-quality' matrices, which are created by alternative agro-ecological techniques, as opposed to the industrial monocultural model of agriculture. Finally, the only way to promote such high-quality matrices is to work with rural social movements currently expanding around the world, thus casting the conservationist in league with the proponents of the concept of food sovereignty.

This new paradigm will obviously be challenging for some in the conservation community as much as it will be for the defenders of 'business as usual' for industrial agriculture. It will be seen as at odds with the major trends of some of the large conservation organizations that emphasize targeted land purchases, as much as large corporate interests that seek further expansion of the industrial agricultural model. We argue that recent advances in ecological research make that general approach anachronistic and call, rather, for solidarity with the small farmers around the world who are currently struggling to attain food sovereignty. They are environmentalist in their own right and the most powerful allies of those who want to conserve the biological diversity of our planet.

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List of abbreviations

BF	Bird Friendly
CBB	coffee berry borer
CEPLAC	<i>Comissão Executiva do Plano da Lavoura Cacaueira</i>
DALR	Direct Action Land Reform
FAO	Food and Agriculture Organization of the UN
GATT	General Agreement on Tariffs and Trade
GEF	Global Environmental Facility
GMO	genetically modified organism
HYVs	high-yielding varieties
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IBRD	International Bank for Reconstruction and Development
ICDP	Integrated Conservation and Development Programmes
IMF	International Monetary Fund
IPE	<i>Instituto de Pesquisas Ecológicas</i> (Institute of Ecological Research)
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
MST	<i>Movimento dos Trabalhadores Rurais Sem Terra</i> (The Movement of Landless Rural Workers)
NAFTA	North American Free Trade Agreement
SAPs	Structural Adjustment Programs
SMBC	Smithsonian Migratory Bird Center
WTO	World Trade Organization
WWF	World Wildlife Fund

Matrix Matters: An Overview

THE BIRDS OF NEW YORK AND THE COFFEE OF MESOAMERICA

Bird-watching requires a morning buzz. The best sightings occur with the rising sun, and even the most enthusiastic bird-watcher normally has to have an all-important cup of Joe before setting out to increment that ever-expanding list of species 'gotten' (the word bird-watchers normally use for 'having seen'). But the association of birds with coffee turns out to be far more important than the casual need for stimulants to get going in the morning.

It all started when someone noticed a striking coincidence: populations of songbirds in the eastern US were declining at the same time as some Latin American countries were engaged in the 'technification' of their coffee production systems in the never-ending quest for higher production. Technification meant elimination of the shade trees that normally covered the coffee bushes in the more traditional form of growing coffee. Those traditional coffee farms were known to be forest-like habitats for various kinds of birds (Figures 1.1 and 1.2). Many of the songbirds that experienced population declines were migratory species that flew south for the winter. Putting a couple of evident observations together, it was not a gigantic leap in logic to suggest that eliminating the shade trees that constituted their wintering habitat would have a significant impact on those birds that sought the tropical climates to avoid the northern winter.

It remains debatable as to how much of the decline in populations of North American songbirds can be directly attributed to the technification of coffee production in Latin America. Regardless, the logic of the situation was enough to mobilize many people – bird-watchers, conservationists, environmentalists – to become apprehensive about this transformation of an agro-ecosystem. And that apprehension was a watershed. Previously, there had always been a kind of knee-jerk attitude that agriculture automatically meant degradation of natural habitat, which obviously translated into a loss of biodiversity, bird and otherwise. But here we have a case where it was arguably the type of agriculture – not the simple existence of agriculture, rather its particular form – that was having an effect on biodiversity.

What emerged from the coffee–biodiversity connection was a new discourse about nature. Previously, conservationists had clearly separated agricultural systems from natural ones in terms of their value for



(a) Black and white warbler



(b) Magnolia warbler



(c) Swainson's thrush

Figure 1.1 Songbirds that are commonly found in coffee plantations in the Neotropics

Sources: (a) and (b) Gerhard Hofmann; (c) Dan Sudia



Figure 1.2 *A shaded coffee plantation that serves as habitat for Neotropical migrants*

Source: Hsunyi Hsieh

biodiversity conservation. But the discovery that many birds apparently could not tell the difference between a diverse canopy of shade trees in a traditional coffee plantation and a diverse canopy of trees in a natural forest caused a reassessment of the very idea of ‘natural’. Was it legitimate to be concerned with keeping the remaining small tracts of untrammelled tropical forest forever untrammelled? If we just ignored the coffee technification were we not insisting that the birds adopt our particular interpretation of what a natural forest was? If the birds were mainly concerned with the existence of shade canopy cover and not so much with where it came from or who managed it (Nature or a farmer), should we maybe rethink our peculiar notion of natural as something managed only by ‘Nature’ and never by a farmer?

The debate still rages. Indeed, this book is in part intended to inform one piece of that debate. On the one hand, it is tacitly assumed that the proper goal is to intensify agriculture so as to produce as much as possible on as little land as possible, thus leaving the maximum possible amount of land under ‘natural’ conditions. On the other hand – and this is our position – agro-ecosystems are important components of the natural world, intricate to biodiversity conservation. Consequently, their thoughtful management should be part of both a rational production system and a worldwide plan for biodiversity conservation. To fully explain our position requires focusing on three areas:

- 1 the nature of biodiversity itself;
- 2 how we have arrived at our current state of agro-ecosystem management; and
- 3 the current way that humans relate to tropical landscapes.

These three areas are the topics of Chapters 2–4. In Chapter 5 we present some examples of how these three areas intersect in the real world. We conclude, in Chapter 6, with our full argument of what we regard as a new practical programme that derives from the underlying social and biological theory.

In the present chapter we provide an overview of the three areas, followed by a glimpse at what we regard as a new paradigm of conservation.

THE ARGUMENT

The ecological argument

In the last few years we have flown over areas that used to be continuous tropical forest in eastern Nicaragua, southern Brazil, southern Mexico, southwestern India and southwestern China. In a very general way, all areas look very similar: a patchwork of forest fragments in a matrix of agriculture (Figure 1.3). With few exceptions (mainly in the Amazon and Congo basins), the terrestrial surface of the tropics looks like this. And we always remain mindful that this is the location of the overwhelming majority of the world's biodiversity. So if we are concerned in general with biodiversity conservation in the world, we ought to be concerned with what is happening in the tropics.

If most of the tropical world is a patchwork of fragments in a matrix of agriculture, and most of the world's biodiversity is located in tropical areas, should we not be concerned with understanding the reality of that patchwork? Yet the vast majority of conservation work concentrates on the fragments of natural vegetation that remain, and ignores the matrix in which they exist. Even at the most superficial level, it would seem that ignoring a key component of what is obviously a highly interconnected system is unwise.

The bias that favours concentrating efforts on the fragments while ignoring the matrix is far more damaging to conservation efforts than first meets the eye. As we argue in detail in Chapter 2, the matrix matters. It matters in a variety of social and political ways, but more importantly, it matters in a strictly biological/ecological sense. Recent research in ecology has made it impossible to ignore this fact. The fundamental idea has to do with the notion of a metapopulation.¹ Many, perhaps most, natural biological populations do not exist as randomly located individuals in a landscape. Rather, there are smaller clusters of individuals that may occur on islands, or habitat islands, or simply form their own clusters by various means. These clusters are 'subpopulations', and the collection of all the



Figure 1.3 *A fragmented landscape in Chiapas, Mexico*

Note: Fragments of natural vegetation are embedded in an agricultural matrix.

Source: John Vandermeer

clusters is a ‘metapopulation’. The critical feature of this structure is that each subpopulation faces a certain likelihood of extinction. Accumulated evidence is overwhelming that extinctions, at this local subpopulation level, are ubiquitous. What stops the metapopulation from going extinct is the migration of individuals from one cluster to another. So, for example, a subpopulation living on a small island may disappear in a given year, but if everything is working right, that island will be repopulated from individuals migrating from other islands at some time in the near future. There is thus a balance between local extinction and regional migration that protects the metapopulation from going extinct at the regional level.

There is now little doubt that isolating fragments of natural vegetation in a landscape of low-quality matrix, like a pesticide-drenched banana plantation, is a recipe for disaster from the point of view of preserving biodiversity. It is effectively reducing the migratory potential that is needed if the metapopulations of concern are to be conserved in the long run. Whatever arguments exist in favour of constructing a high-quality matrix, and there are many, the quality of the matrix is perhaps the critical issue from the point of view of biodiversity conservation. The concept of ‘the quality of the matrix’ obviously must be related to the natural habitat

that is being conserved, but most importantly, it involves, at its core, the management of agricultural ecosystems.

The agro-ecological argument

When considering agriculture, the research establishment has become mesmerized by a single question: How can we maximize production? Rarely is it acknowledged that such a goal is really quite new, probably with a history of less than a couple of hundred years, and little more than 50 years old in its most modern form. In recent years there have been major challenges to this conventional agricultural system, all of which, in one form or another, involve questioning this basic assumption. Why should it be a goal at all to maximize production? We return to this question in Chapter 3. But for now, suffice it to say that many analysts have concluded that environmental sustainability, social cohesion, cultural survival and other similar goals are at least equally as important as maximizing production, creating two attitudinal poles in what has become as much an ideological struggle as a scientific debate.

This fundamental contradiction in attitudes is reflected most strongly in the alternative agricultural movement, especially among those who study agriculture from an ecological perspective. There is a distinct feature of more ecologically based agriculture that must be recognized here. Ecological scientists, in general, tend to have a certain mind-set, largely derived from the complexity of their subject matter. This mind-set is most easily appreciated by comparing the mind-set of a typical agronomist with a typical ecologist, especially an agro-ecologist. Both seek to understand the ecosystem they are concerned with, the farm or the agro-ecosystem. And both have the improvement of farmers' lives as a general practical goal. But the way they approach that goal tends to be quite different.

Consider, for example, the classic work of Helda Morales.² In seeking to understand and study traditional methods of pest control among the highland Maya of Guatemala, she began by asking the question, 'What are your pest problems?' Surprisingly, she found almost unanimity in the attitude of the Mayan farmers she interviewed – 'We have no pest problems.' Taken aback, she reformulated her question, and asked, 'What kind of insects do you have?', to which she received a large number of answers, including all the main characteristic insect pests of maize and beans in the region. She then asked the farmers why these insects were not a problem for them, and again received all sorts of answers, always connected to how the agro-ecosystem was managed. The farmers were certainly aware that these insects could be problematic, but they also had ways of managing the agro-ecosystem so that the insects remained below levels that would categorize them as pests. Morales' initial approach was probably influenced by her original training in agronomy and classical entomology, but her interactions with the Mayan farmers caused her to change that approach. Rather than study how Mayan farmers solve their

problems, she focused on why the Mayan farmers do not have many pest problems.

Here we see a characterization of what might be called the two cultures of agricultural science: that of the agronomist (and other classical agricultural disciplines such as horticulture, entomology, etc.) and that of the ecologist (or agro-ecologist). The agronomist asks, 'What are the problems the farmer faces and how can I help solve them?' The agro-ecologist asks, 'How can we manage the agro-ecosystem to prevent problems from arising in the first place?' This is not a subtle difference in perspective but rather a fundamental difference in philosophy. The admirable goal of helping farmers out of their problems certainly cannot be faulted on either philosophical or practical grounds. Yet with this focus we only see the sick farm, the farm with problems, and never fully appreciate the farm running well, in 'balance' with the various ecological factors and forces that, in the end, cannot be avoided. It is a difference reflected in other similar human endeavours – preventive medicine versus curative medicine, regular automotive upkeep versus emergency repair, etc. The ecological focus of asking how the farm works is akin to the physiologist's focus of asking how the body works. The agronomist only intervenes when problems arise, the agro-ecologist seeks to understand how the farm works and thus how it is maintained free of problems. Agronomists seek to solve problems, agro-ecologists seek to prevent them.

Why is this debate important for the conservation of biodiversity? If we accept the fact that most tropical areas are highly fragmented and that for biodiversity conservation the matrix matters, and we recognize that 'the matrix' consists of managed ecosystems, mostly agriculture, then the way we manage those agricultural systems becomes crucial for biodiversity conservation. If, as we noted above, all populations are metapopulations, migrations among natural habitat fragments is key to their conservation, and those migrations do not occur in a low-quality matrix, which is to say a biodiversity-unfriendly agricultural ecosystem. The rest of this book makes the case for the intricate connection between biodiversity and that human activity we call agriculture. We argue for a new paradigm for biodiversity conservation. That paradigm acknowledges what we now know about ecology: that the agro-ecosystem in which natural habitats are embedded is important. Recognizing this implies a connection with the effective planning that has occurred and still does occur in the agricultural sector. And this brings us to the question of rural social politics.

The rural grass roots argument

A traditional way of designing an agro-ecosystem is by reference to ecological structures that exist in surrounding vegetation, a vision sometimes referred to as 'natural systems' agriculture.³ Thus, for example, agriculture in grassland areas (which is where the most important cereal production in the world occurs) has recently been less environmentally sound than we

might wish because it is designed to be an artificial annual monoculture whereas the native vegetation is a perennial polyculture.⁴ The fact that we produce annual monocultures in these regions is simply due to the lack of available domesticated perennial grasses and the knowledge of how they might be productively managed. Other examples could be cited, but the principle is obvious – we should take cues from the natural world as to how to construct agro-ecosystems.

However, if this sort of ecologically complex ‘natural systems’ design is to be carried out, it is necessary to look to the actual practices that are currently in place. And when we do that, we are struck with the similarity between ‘natural systems’ agriculture and the way the vast majority of small-scale farmers in the tropics actually do plan their farms. Indeed, as we argue more comprehensively in Chapters 3–5, we already have a model for the way in which agriculture ought to be practised if it is to be biodiversity-friendly. Naturally the issue is complex, as all socio-political issues are, but the underlying idea behind the complex realities is that small-scale farming in the tropics has been and to a great extent continues to be based on something similar to ‘natural systems’ agriculture – what many farmers in the Global South refer to as ‘agro-ecology’ (Figure 1.4).



Figure 1.4 *Small-scale indigenous farmers in the highlands of Peru participating in the faena (collective work)*

Note: The farmers’ traditional agricultural system is based on cultivating a variety of crops that are native to the region and highly adapted to local conditions. Their farming methods incorporate many agro-ecological techniques.

Source: Julio Valladolid

Overriding this fundamental ecological and economic framework is a political one. The very farmers who practise agro-ecological methods have frequently been driven off their lands, legally or not, and those who have preserved their farms are today faced with enormous economic, ecological, and political pressures. As a consequence, a large number of rural political movements have sprung up to challenge the international system that, to their minds, has created most of their problems. These movements are large, and tremendously diverse. However, within this diversity there seems to be emerging a framework that is remarkably all embracing: the idea of food sovereignty. That is, couple the venerable idea of food security with the fundamental right of farmers to land, water, seeds and other means of production, as well as the rights of rural communities to decide what and how to produce, and the basic plan of food sovereignty emerges.⁵ It is a movement for farmers' rights as much as the general right to adequate food, and recounts the old cliché, 'give a woman a fish and she eats for a day, teach her how to fish and she eats forever'. It could be rephrased, 'give a local community big bags of grain and they will eat for a week. Construct socio-political, economic systems that allow the farmers in the community to produce the necessary food, and the community will eat forever.'

While there are many obvious reasons for wanting food sovereignty, for the specific purposes of our argument the crucial aspect of this new social movement is that it normally contains within it the assumption that the production system will preserve biodiversity and be based, to whatever extent possible, on the functioning of the local natural system. This is precisely what we claim is needed.

TOWARDS A NEW PARADIGM

In the rest of this book we develop our argument in great detail. But its outline, we feel, is clear from this introductory chapter. It is a three-part story, with the parts interrelated in complicated ways, each with its own complex historical roots, but fundamentally, telling a simple story. First, in fragmented landscapes, seemingly the predominant landscapes in most tropical areas of the world, the balance between extinction and migration is what determines whether a species will survive over a large area – there is no question that it will periodically go extinct in particular fragments, but the key issue is whether that extinction event will eventually be countered by a migration event or will eventually become part of a regional extinction. Second, the matrix in which the fragments occur is mainly devoted to agriculture of various kinds, and the particular form of agriculture may or may not be biodiversity-friendly, either in its ability to preserve directly some forms of life or in its ability to act as a passageway for migrating organisms. Third, this matrix is constructed primarily by small farmers, many of whom struggle to survive in the current political

and economic climate, and have consequently developed a worldwide movement to transform agriculture from its post-World War II form (so heavily dependent on biocides and chemical fertilizers) to a more ecologically sound form.

Our new paradigm incorporates these three issues into a prescriptive whole.⁶ Support for the worldwide food sovereignty movement results in promotion of biodiversity-friendly agricultural methods that encourage high-quality matrices, thus increasing migration coefficients to balance the inevitable extinction coefficients that exist in natural habitat fragments. It is a paradigm that suggests a reorientation of conservation activities, away from a focus on protected areas and towards the sustainability of the larger managed landscape; away from large landowners and towards small farmers; away from the romanticism of the pristine and towards the material quality of the agricultural matrix, Nature's matrix. At the centre of this new paradigm is the urgent need for social and environmental justice, without which the conservation of biodiversity ultimately becomes an empty shibboleth.

NOTES

- 1 Hanski (1999).
- 2 Morales and Perfecto (2000).
- 3 Altieri (1987); Ewel (1999).
- 4 Jackson (1980).
- 5 'Food Sovereignty: A Right for All' (2002), Political Statement of the NGO/CSO Forum for Food Sovereignty, Rome, 8–13 June, www.foodfirst.org/progs/global/food/finaldeclaration.html, accessed 22 December 2008.
- 6 Vandermeer and Perfecto (2005b; 2007a,b); Vandermeer et al (in review).

The Ecological Argument

THE FUNDAMENTAL PATTERNS OF BIODIVERSITY

When the popular media approach the issue of biodiversity, the subject matter is almost always about charismatic megafauna – tigers, elephants, pandas and the like. We too lament the probable extinction faced by these evocative creatures. The world will surely be diminished as the last wild gorilla is shot by a local warlord beholden to one or another political ideology, or even as a rare but beautiful bird species has its habitat removed to make way for yet another desperately needed row of shops. The irony is gut-wrenching to be sure. However, such concerns are the very small tip of the very large iceberg. If we simply take mammal diversity as an estimate of the number of creatures that are likely to be thought of as charismatic by the general public, we are talking about approximately 4500 known species. By comparison, there are currently about 900,000 known species of insects, and that is almost certainly a gross underestimate of how many actually exist. We have no idea how many species there are, since estimates range from about 2 million to as high as 30 million.¹ While the latter estimate is probably exaggerated, even if there are only 2 million species of insect, we see that a focus on the 4500 species that happen to look more or less like us, is limited to a rather small fraction of the Earth's biodiversity. And to make the point even more dramatic, consider the biodiversity of bacteria. Microbiologists define two bacterial cells to be in the same species if their DNA overlaps by 70 per cent or higher, which, if applied to mammals, would put all primates (if not all mammals) in the same species. Simply from the point of view of numbers, the world of biodiversity is mainly in the small things, from bacteria to insects, leaving the charismatic megafauna as a rather trivial subplot to the main theme.

Apart from these dramatic patterns associated with classifying life, biodiversity manifests itself in a variety of other patterns. For convenience of presentation, we identify four:

- 1 Biodiversity tends to increase and then undergo massive and rapid extinctions at periodic intervals, at least for the past 600 million years – an evolutionary pattern.
- 2 Species diversity tends to increase with decreasing latitude and altitude – a geographic pattern.

- 3 Species diversity tends to decrease on islands when the island is smaller and/or more distant from the mainland – an insular pattern.
- 4 Species diversity tends to decrease as the intensity of management of the ecosystem increases – an intensification pattern.

Each of these patterns is relevant to the general topic of how to conserve biodiversity. We summarize each of them in turn.

Evolutionary pattern: diversity through time

When the Earth began, almost 5 billion years ago, it was void of any life, as far as we know. For more than a billion years it was bombarded by meteors, and there is some speculation that life could have originated many times, only to be destroyed each time by a meteor. Nevertheless, the earliest solid evidence we have for life on Earth is in some fossils, structurally similar to bacteria, from about 3.5 billion years ago. The actual process of photosynthesis evolved at some point around 3 billion years ago, and can be thought of as the first major biological revolution in the history of the Earth. Before the evolution of photosynthesis the atmosphere was virtually devoid of oxygen. Yet now, and for the past 2 billion years, not only does the Earth's atmosphere have an abundant supply of oxygen, but the majority of life forms actually depend on oxygen for generating energy.

During the enormous period in which oxygen was accumulating in the environment, it is likely that there was some sort of evolutionary pressure for increasing size, although exactly which environmental force may have produced that pressure is at best a matter of speculation. Nevertheless, in order to get larger, it was necessary to have more organization in the cell, which gave rise to the partitioning of the hereditary material within a membrane, what we today call the nucleus of the cell. Then, in one of Nature's greatest revolutions, a parasitic bacterium which invaded a cell in the same way bacterial parasites do today, gradually evolved a lower toxicity and the attacked cells gradually evolved the ability to take advantage of the biochemical apparatus that the parasite used for energy generation, leading to one of the most important symbiotic relations in the history of life. This was, by most accounts, the origin of the mitochondria, the small structures inside the cell that are responsible for producing the energy the cell needs to carry on its regular activities.² A similar story can be told for chloroplasts, the small structures inside plant cells that contain the biochemical machinery for photosynthesis.

The result of all this new organization was a new type of cell, with an obvious high level of organization within the cell itself: a nucleus, mitochondria, chloroplasts (for plants) and many other evident structural details. This was the eukaryotic cell, which first appeared about 1.75 billion years ago. All previous life forms were very small cells, the size of today's bacteria, a type of cell organization referred to as prokaryotic.³

The next major event in the evolution of biodiversity was the ability of cells to associate with one another, which, in addition to the need for a way of sticking together, also required some sort of communication system among cells. This cell-to-cell signalling is a major area of biological research today, but for purposes of the present discussion, we only need to note that the ability to engage in communication between cells that were able to physically stick together was another major evolutionary event: the first multicellular organisms. This happened about a billion years ago.

Then the most amazing, and even perplexing, event took place. Around 600 million years ago, there was an explosion of life forms. There suddenly appeared almost all the major forms of animals we know today. Within a very short window of time, perhaps as short as 30 million years, the Earth went from almost no multicellular life to a rich diversity of such life. This event has been termed the Cambrian explosion, based on the classical name for Wales, location of the site where some of the first fossils of this period were originally discovered and studied. And not only was it a rich diversity of life forms, it was the origin of all the basic body plans we see today, according to some palaeontologists.⁴ That is, we went from almost no multicellular biodiversity to 'all' the basic diversity of forms the world has since known, in a period of only 30 to 40 million years – a blink of the eye in geological time.

Naturally, when we say 'all' the biodiversity, this implies something about the level of diversity under consideration. We actually had 'all' the world's biodiversity about 1.75 billion years ago when the evolution of eukaryotic cells added a third basic body plan to the mix of only bacteria and a similar group of prokaryotic organisms, the Archaea. At this basic level of organization, we have not seen any new innovations in the past 1.75 billion years. But moving to a lower taxonomic level, what we see in the Cambrian explosion is the sudden appearance of all the basic body plans we know today, among the animals, plus a variety of other basic plans that do not seem to have survived into modern times.

An example of the basic body plans that did not survive to the present day is that of the trilobites. These were animals whose segmented body was arranged in three longitudinal lobes, almost as if they were segmented in two dimensions (segments along the body from front to back, but also the three segments, or lobes, from side to side). In some sense these were the most successful large multicellular organisms that have ever lived. They were incredibly diverse – big ones, small ones, ones with plain bodies, ones with spines and other ornaments. And they were always a numerically significant component of all oceans. Of course they shared their environment with many other forms, memorialized in the description of the famous Burgess Shale in Stephen J. Gould's delightful book *Wonderful Life*.

The Cambrian explosion was followed by several major diversification patterns, each interrupted by general extinctions. Indeed, the formal geological names given to various segments of life's history in the

post-Cambrian explosion world correspond to periods between these general extinction events. Diversification followed by extinction was the rule of evolution for all post-Cambrian time. But there would be a truly catastrophic event about 330 million years after the beginning of the Cambrian period. For reasons that remain obscure, almost all animal species and many plant species disappeared! This event is referred to as the Permian extinction, and marks the final demise of that basic body plan so common in all oceans for the prior 330 million years – the trilobites.

The ensuing 180 million years saw the rise to dominance of the dinosaurs. If we can categorize the first 330 million years after the Cambrian explosion as the age of the trilobites, the next 180 million can be called the age of the dinosaurs. Dominating the terrestrial environment the world over, the dinosaurs diversified three distinct times, each of which was interrupted by a mass extinction, giving rise to the threesome: Jurassic, Triassic and Cretaceous, names for the interludes between the extinction events. It should be noted that mammals also first evolved at the beginning of this dinosaur age, but they never diversified to any degree and remained a small and minor component of terrestrial biodiversity during this entire period.

About 65 million years ago the Earth was subjected to a calamity of such proportions that we can hardly imagine it. A giant asteroid smashed into a point currently located in the northern Yucatan peninsula of Mexico. This event caused dramatic and sudden changes in our planet's environment such that the dinosaurs, to the very last one of them, were eliminated from the Earth's surface. While it is not clear exactly why the asteroid caused such a dramatic extinction event (in other words, it could have been the elimination of their food supply, or the contamination of the air, or perhaps some other catastrophic change), the fact of the asteroid being the causative agent, is no longer contested.

The elimination of the dinosaurs from the planet dramatically lowered worldwide biodiversity for a short period of time, as happens after every major extinction event. However, soon thereafter we see another diversification: the rise of the mammals, birds, insects and flowering plants to a position of dominance in the terrestrial world. Indeed, the basic structure of terrestrial ecosystems as we know them today originated late in the dinosaur age and became dominant after the crash of the asteroid. Flowering plants capture energy through photosynthesis, and the insects that pollinate their flowers facilitate their main form of sexual reproduction. Birds, mammals and some insects are frequently responsible for dispersion of their seeds, the second aspect of reproduction.

In sum, over geological time we have seen four major divisions in the qualitative nature of the Earth's biodiversity: first, prior to the Cambrian explosion, the pre-Cambrian era, second the age of the trilobites (formally known as the Palaeozoic era – old life), third, the age of the dinosaurs (formally known as the Mesozoic era – middle life), and fourth, the age of the mammals (formally known as the Cenozoic era – new life, and

including flowering plants, birds and insects). Today we are living in the Cenozoic era, which is still very young.

This brief overview of biodiversity over time makes it clear that the biodiversity we have today on our planet is the result of an evolutionary process that started 3.5 billion years ago and that has undergone periods of diversification and extinctions, even mass extinctions many times, well before humans first appeared on Earth just a geological instant ago. It has been estimated that well over 99 per cent of species that have ever existed on Earth have already become extinct. While even this may be an understatement, it is nevertheless adequate to make the point that extinction is a natural and normal process. The fact that the extinction rate today appears to be on the order of past mass extinctions is worrisome and is the reason we are all concerned about biodiversity conservation (recall that it took about four million years for evolution to recuperate from the last extinction event). However, there is no denying that extinction is part and parcel of the overall evolutionary dynamics of life on Earth. As we shall see later in this chapter, extinction remains an important force, although it is a complicated one that must be appreciated for what it is. The Sisyphean struggle to stop all extinctions in all parts of the globe may not only be frustrating for conservationists, but may also in the end be bad conservation policy – a point we discuss in some detail as our argument unfolds.

Geographic pattern: biodiversity changes with latitude and altitude

One of the most obvious patterns in the biological world is the dramatic difference between temperate and tropical regions. In a one-hectare plot of land in Michigan, we have identified 16 different species of trees. In a one-hectare plot of land in Nicaragua, we have identified 210 different species of trees. And such differences exist for almost all groups of species. The bird guide of Colombia lists 1695 species, while in all of North America (a much larger area) there are approximately 932 species. Butterflies, ants, mammals and amphibians all show this same pattern. There are definite exceptions (some notable ones are sea birds, organisms of the deep ocean floor and lichens), but the general pattern is one of increasing numbers of species as you approach the equator.

This pattern has been the subject of an enormous amount of speculation and debate in ecology. Many hypotheses have been suggested to explain it. One scientist, combing the literature, found a minimum of 21 distinct hypotheses laying claim to explaining the pattern.⁵ At present, there is no final agreed-upon theory that satisfies all biodiversity scientists.

A very similar pattern exists with respect to altitude – there are very few species at higher elevations, and more species at lower elevations. All the hypotheses as to the underlying cause of latitudinal gradients have also been suggested for the altitudinal gradient, and are likewise not agreed upon by biodiversity scientists.

The practical political implications of this latitudinal pattern are extremely important, and form one of the foundations for our basic argument. It is in the tropics where the bulk of the world's biodiversity lies, and it is also in the tropics where most of the poor people in the world reside. It is also in the tropics where there is still a large rural population whose livelihood depends on agriculture. The connection between rural people in the tropics and biodiversity conservation is at the heart of the new conservation paradigm presented in this book. We revisit this point several times in the development of our thesis.

Insular pattern: biodiversity on islands

One of the most noted patterns of biodiversity is seen on islands. Generally, there are more species on larger islands and more species on islands nearer to the mainland. Nevertheless, exactly how many more species will be found on an island twice the size of another island, remains highly variable. Despite this variability, it is a general rule of thumb that if you plot the logarithm of the number of species against the logarithm of the size of the island, you get a straight line.

Explanations of this pattern generally fall into three categories. First, it may be simply a sampling problem. This is certainly part of the explanation and is extremely important when it comes to the difficult issue of sampling biodiversity. Even today, the technical literature is filled with the elementary error of determining species richness in a series of samples and then taking the average of those determinations as the estimate of species richness in that environment. Because species accumulate non-linearly with increasing sample size, this procedure is fundamentally wrong and can give highly misleading results.

The second category has to do with environmental heterogeneity. It seems obvious that a larger area, be it a sampling unit or an island, will probably contain more microhabitats than a smaller area and thus provide more 'niches' for species to fill.⁶ In the end this explanation falls within the general category of differing extinction rates (if a new species arrives at an island but fails to locate its habitat, it becomes extinct), and is part of the theory of island biogeography, as discussed presently.

The third category is an equilibrium balance between migration and emigration rates, first fully elaborated by Robert H. MacArthur and Edward O. Wilson in their classic work *The Theory of Island Biogeography*.⁷ The basic idea is that populations of organisms are always dispersing in one way or another. Any area is thus likely to receive migrant individuals at regular intervals, whether in the form of a dispersed seed of a plant or a migrant individual bird or bat, or the propagule of a micro-organism. On an island one could, theoretically, sample all those incoming organisms and determine which ones were new to the island and which ones had been living on the island already. The rate at which *new* species arrive on the island is the immigration rate. Also, if you had enough helpers and

technology, you could keep track of all the organisms on the island, and thus know when any particular species completely disappeared, which is to say when it becomes extinct, on that particular island. Then, if the rate of extinction is greater than the rate of immigration, the total number of species on the island would decline. Similarly, if the rate of immigration is greater than the rate of extinction, the number of species would increase. The perfect balance, known as 'the equilibrium number of species', is when the extinction rates and immigration rates are the same (Figure 2.1).

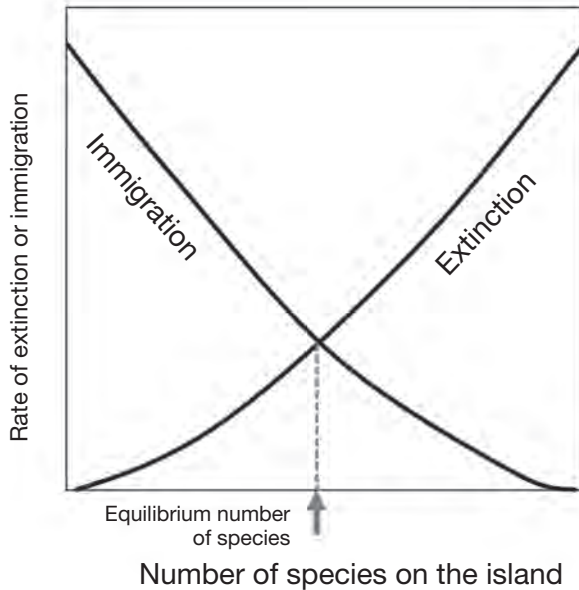


Figure 2.1 *The theory of island biogeography developed by Robert H. MacArthur and Edward O. Wilson*

Note: The number of species found on an island can be determined by the balance between immigration and extinction rates.

Source: The authors

This third category, the equilibrium theory, has been employed in many different guises in ecology and, especially today, is implicated in all sorts of practical problems ranging from the ideal design of a nature reserve to the underlying reason why tropical rainforests have so many species of trees. In conservation biology, the theory is applied to habitat islands (e.g. fragments of forests), and it is often assumed that the agricultural matrix that surrounds these 'islands' is like the ocean in real oceanic islands and therefore devoid of terrestrial biodiversity. One of our arguments, and one that we elaborate further in Chapters 3–5, is precisely that the agricultural matrix is nothing like the ocean, devoid of terrestrial biodiversity. On the

contrary, the agricultural matrix can act as a refuge for biodiversity as well as a facilitator of movement of organisms between the 'islands' of forest. When combined with the related subject of metapopulation theory (discussed later in this chapter), it is also a major feature of the most recent refocusing of the conservation agenda, the new conservation paradigm, and the subject matter of this book.

Intensification pattern: changes in biodiversity with management

Over 50 per cent of the terrestrial surface of the Earth is covered with managed ecosystems.⁸ In the popular and romantic conceptualization of Nature as a Garden of Eden, many conservationists think of agriculture as the defining feature of biodiversity loss. The world gets divided into those areas untouched or minimally touched by *Homo sapiens* as contrasted to those areas 'despoiled' by human activity. One of the main observations that caused a re-evaluation of this prejudice was the correlation between the decline of populations of songbirds in the eastern US and the transformation of the coffee agro-ecosystem of Mesoamerica. As detailed in the previous chapter, the traditional method of coffee production includes a diverse assemblage of shade trees with the coffee bushes growing as if they were part of a forest understorey. These coffee plantations appeared to be forested land if viewed from above and it has now been convincingly demonstrated that they are important habitats for those very bird species from North America when they migrate south for the winter.⁹ This key observation has been significant in demonstrating that agro-ecosystems can be critical repositories of biodiversity, but even more importantly, that the particular type of agricultural practice can be a determinant of the biodiversity the ecosystem contains. Not all coffee plantations harbour high levels of biodiversity, and the characterization of what types of agro-ecosystems generally harbour greater or lesser amounts of biodiversity has only recently emerged as a serious scientific question.

When dealing with managed ecosystems it is first necessary to distinguish between two concepts of biodiversity. First, the collection of plants and animals that the manager has decided are part of the managed system – rice in the paddies of Asia; maize, beans and squash in the traditional fields of Native American Mayans; carp in the fish ponds of China, etc. This is referred to as the 'planned' biodiversity, or sometimes the 'agribiodiversity'. Yet in each of these ecosystems there is almost always a great amount of biodiversity that spontaneously arrives – the aquatic insects and frogs in the Asian rice paddies, the birds and bugs that eat the Mayan's *milpas*, the crayfish that burrow their way into the sides of the Chinese fish ponds. This is referred to as the 'associated' biodiversity or 'wild biodiversity'. Frequently the managers themselves are determinedly concerned about the planned biodiversity, especially when dealing below the species level (in other words, with genetic varieties of crops). However,

it is almost certainly the case that the associated biodiversity is the most abundant component of biodiversity in almost all managed ecosystems, and as such, it has received a great deal of attention in recent years.

Although the term 'agricultural intensification' has a very specific and complex definition in anthropology, in the biodiversity literature the term 'management intensification' is taken to be the transition from ecosystems with high planned biodiversity and a more traditional management style to low planned biodiversity and an industrial management style, such as the use of agrochemicals. So, for example, in the case of coffee just mentioned, the intensification of coffee refers to the reduction of shade trees ending up with an unshaded coffee monoculture. The ecology of the agro-ecosystem is such that the final stages of intensification usually involve the application of agrochemicals to substitute the functions or ecosystem services of some of the biodiversity that is eliminated. The coffee example will be discussed in more detail in Chapter 5.

The main question of concern is how the pattern of associated biodiversity changes as a function of the intensification of agriculture. This question remains largely unanswered for almost all agro-ecosystems and almost all taxa. The few studies that actually ask this question come up with results that depend on the taxon involved and even the definition of what constitutes greater or lesser intensity. But that said, it is possible to make one central generalization: biodiversity declines with agricultural intensification. Most of the patterns described in the literature can be summarized into two basic prototypes of associated biodiversity change as a function of intensification (Figure 2.2). First, as tacitly assumed by

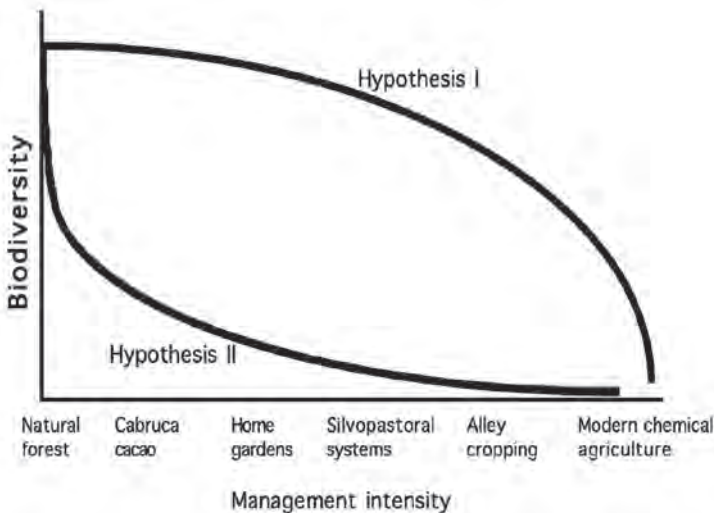


Figure 2.2 *Two hypotheses about the relationship between management intensity and biodiversity*

Source: The authors

many conservation practitioners, as soon as a natural habitat is altered by a management system, associated biodiversity tends to fall dramatically. Second, as has been shown in several cases, associated biodiversity declines by only small amounts with low levels of intensification and only after much higher levels are reached do we see dramatic declines. Which of these two patterns (or what combination of the two) exists in particular systems is largely unknown because this question has not been a popular one amongst those concerned with biodiversity – a major intellectual lacuna in conservation biology.

Indeed, it is frequently the case that conservation practitioners pay little attention to agro-ecosystems or forestry systems or aquatic managed systems. The assumption seems to be that once management activities are initiated in an area, the question of biodiversity becomes irrelevant. From a strictly intellectual point of view this position is simply one of ignorance. But from a practical point of view it is a position that could have devastating consequences when it comes to biodiversity conservation itself. If a minimum of 50 per cent of the world's surface is covered in managed ecosystems, and if managed ecosystems contain even a small fraction of the biodiversity contained in unmanaged ecosystems, ignoring them will be counterproductive, to say the least.

While many agro-ecosystems are tremendous reservoirs of biodiversity and deserve attention for that reason alone, there is another reason why the intensification gradient is important to biodiversity conservation – agro-ecosystems form the matrix through which organisms must travel as they move among natural habitat fragments. The pesticide-drenched rice field is hardly convivial to biodiversity generally, but is also not a habitat through which some organisms are likely to travel. An anecdote perhaps helps make our point. In conversation with a local bird-watching enthusiast in the coffee-growing areas of southern Mexico, we mentioned the highland guan, a rare forest bird species in the area. We asked if the species is ever seen in the abundant shade-coffee farms in the area. After some thought, the answer was 'hardly ever'. We immediately focused on the word 'hardly'. The highland guan will not live in a coffee plantation, but it will cross over one in pursuit of a new patch of forest. Will it do the same in a non-shaded plantation, or a maize monoculture? The issue is not whether species are able to form successful populations in these matrix habitats, it is whether they will ever venture into them at all. If not, the matrix in fact is that impenetrable ocean, devoid not only of permanent biodiversity, but also of any migratory potential.

The relationship between biodiversity and the intensification of agriculture is a key component of the argument developed in this book, and is further elaborated in Chapters 3 and 5.

WHY THE BIODIVERSITY PATTERNS MATTER

To some extent these four biodiversity patterns have been examined independently by biodiversity scientists. Here we consider them together because of their importance to the general theme of this book. Each pattern touches on an important aspect of what we are calling a new paradigm of biodiversity conservation.

The pattern of evolution and extinction through time has been the domain of palaeontologists and evolutionary biologists who seek to understand the reasons those patterns exist. Its importance to our general theme is the remarkable fact that probably over 99 per cent of all species that have ever existed are already extinct. Extinction is a major fact of biology. While the massive extinctions associated with the end of each geological period are truly spectacular, a more important fact is that local extinctions occur all the time. These local extinctions are an important part of the ecological side of our story.

The tropical world has attracted the attention of ecologists for years and has led to the posing of some of the most important and still enigmatic questions concerning biodiversity, particularly about how it is maintained. We explain these problems later in the chapter. However, it is worth noting that the vast majority of the world's biodiversity is located in the tropics, precisely where the vast majority of the world's poverty is also located. This conjunction of biological fact with political reality creates important imperatives for the conservation agenda.

The fact that more species live on larger islands than on smaller ones creates a backdrop for understanding how species fit together in ecosystems. Beginning with, as we noted, the basic idea of a balance between extinction and immigration of species, we move into a very similar idea of extinction and immigration of individual populations, and from the patterns that exist on oceanic islands to the patterns that exist on habitat islands, and then to the patterns that exist in fragmented landscapes dotted with patches of natural habitats. This general pattern is also key to the ecological side of our argument.

That biodiversity tends to decline with agricultural intensification is perhaps the most important pattern of all. At a trivial level, since agriculture is invariably implicated in the process of habitat fragmentation, if one is concerned about what happens to the biodiversity as that fragmentation proceeds, it would be somewhat naïve to simply ignore the habitats that arguably occupy most of the landscape. But beyond this obvious issue, as we argue more completely in Chapters 3 and 5, the matrix within which the fragments will be located is for the most part composed of agriculture. Therefore, how that agriculture either promotes or endangers biodiversity is a key issue when assessing the quality of the matrix.

THE ECOLOGICAL BACKGROUND TO BIODIVERSITY STUDIES

From the paradox of the plankton to metapopulations

There has always been a bit of an enigma concerning highly biodiverse ecosystems, even though its significance has largely remained buried in the back alleys of esoteric ecological theory. According to fundamental ecological principles, there really should not be as much biodiversity as we see in some places. The more than 400 species of trees you can find in one hectare of an Amazonian forest, for example, live in a way that is impossible, according to classical ecological theory. The reason for this is neither elementary nor, in the end, correct, but for years there has been a fundamental contradiction between what most ecologists believed about biodiversity maintenance and the reality of the hyper-diversity of the tropics.¹⁰

According to classical theory, biodiversity can be thought of as metaphorically equivalent to a game of musical chairs. If you have 10 chairs and 11 people, once the music stops, one person is eliminated and a temporary adjustment of number of people to number of chairs is achieved. In the classical theory the chairs represent distinct resources or ecological niches, and the people represent species that need those resources/niches in order to survive. The theory says, simply, there can be no more people than there are chairs, no more species than there are niches (resources needed by particular species), and it is known as the 'competitive exclusion principle'.

The great ecologist G. Evelyn Hutchinson, assuming the principle of competitive exclusion, noted that many communities contain species that would be difficult to characterize as having distinct niches in the first place. Consider, for example, phytoplankton, the small photosynthetic organisms that passively float in the open water of lakes and oceans. A given lake, or a given section of ocean, will contain many species, all of which more or less passively float, absorb light for photosynthesis and use the resulting nutrients. It is difficult to imagine how so many species in such a uniform environment could be partitioning some aspect of the environment into separate resources or different niches. Here, then, was a paradox. Hutchinson called it 'the paradox of the plankton' and it has become a touchstone for biodiversity studies ever since. Different species of plankton seem to all do the same thing, which, according to the classical theory, means that they cannot coexist. Yet so many of them do. There is only a single chair in the musical chairs game, yet somehow all 11 people seem to keep playing the game.

Contemporary ecology is converging on a body of evidence that challenges the classical theory. If we stick with the musical chairs metaphor, the new theory sees ecosystems as organized according to a collection

of musical chair games, with groups of chairs arranged in small clusters around the room, and those people excluded from one cluster managing to run quickly to another cluster to find a seat. That is, the classical equations that described the way species interact with one another have been expanded in several ways, and we now have a more complicated and realistic view of how biodiversity is organized. The spatial distribution of individuals within a species, the non-linear ways they interact with one another, along with their random movements, all fit into a new paradigm of biodiversity maintenance. It is still the case that the most fundamental ecological principles tell us that there can be no more species than there are resource types, but modern principles add spatial distribution, non-linearities and chance to the debate, resulting in a far better fit between the real world and the theoretical world of the ecologist.

The basic structure of this new formulation has some points in common with the now well-accepted equilibrium theory of island biogeography, the theory that effectively explained the basic pattern of biodiversity on islands, as described earlier in this chapter. What MacArthur and Wilson, co-inventors of the theory, basically did was change the focus of biodiversity studies from an emphasis on the competitive exclusion principle, to an emphasis on extinction and migration processes. Continuing with the musical chairs metaphor, they asked not how individuals were competitively excluded due to the unavailability of chairs, but rather how fast they were excluded from one cluster of chairs, and whether or not they could get from one cluster to another. In other words, they changed the focus from asking about competition among species to asking about the balance between migration and local extinction.

This new focus was morphed by ecologist-epidemiologist Richard Levins to examine the balance between extinction and migration, not of species, but of subpopulations, groups of individuals belonging to the same species, but grouped on islands, or habitat patches, or somehow separated from other such groups of individuals of the same species.¹¹ The collection of these subpopulations became known as a metapopulation.¹²

Understanding the principles of metapopulations is probably easiest with reference to the classical framework employed by epidemiologists when studying diseases. Normally we consider an individual person as either susceptible to a disease or already infected with it. We can also become immune to many diseases, but we shall ignore this fact for now. Being infected means that the organism that causes the disease has invaded the body of the individual in question. The familiar trajectory for non-lethal diseases is that an individual becomes infected but then his or her body fights off the infection and becomes cured, and, unfortunately, liable to infection all over again, which is to say, they go back again to the susceptible category. So, epidemiologists usually ask, what proportion of the human population is currently sick, how fast do they get cured, and how fast do they become infected again? Becoming infected depends on the transmission rate of the disease organism, which is effectively the same

as the migration rate. Becoming cured means that the disease organism became extinct in that particular person's body. The course of the disease is a consequence of the balance between the rate at which new individuals become sick (the migration rate of the disease organism) and the rate at which sick individuals get better (the local extinction rate of the disease organism).

Applying this epidemiological formulation to the problem of how species are maintained, the idea is that sick or well people represent metaphorical habitats, and the disease organism either inhabits them or not. So, rather than think of human bodies, think of islands or patches of particular kinds of habitat that may or may not contain individuals of a particular species. In metapopulation analysis, we ask what fraction or percentage of all the available habitats actually contains a subpopulation of the species of concern. That is the variable of analysis, usually designated with the symbol p . Then we ask what is the rate at which subpopulations become extinct (equivalent to the rate at which individuals become cured of the disease), and what is the rate at which habitats that did not contain individuals of this species actually receive migrants (the migration rate). The most important result of this theory is that over the long run p is equal to 1.0 (100 per cent minus the ratio of extinction (e) to migration (m), ($p = 1 - e/m$). So, for example, if the migration rate is very high relative to the extinction rate, the ratio e/m will be close to zero and the equilibrium occupation of the habitats will be close to 100 per cent. If the migration is reduced to the point that it is almost equal to the extinction rate, the ratio e/m will be almost 1.0, which means that the occupation of the habitats will be close to zero, and the population, the entire metapopulation, will become extinct (Figure 2.3).

With this theoretical framework we see the importance of distinguishing between local extinctions (which are natural and unavoidable, the e in the basic equation) and 'global' or 'regional' extinction which is the condition where all subpopulations have disappeared. The goal of conservation, at its most elementary level, is to try to make sure that p stays greater than zero. Metapopulation theory tells us that to do so we need to concentrate on m , as well as e .

The importance of extinctions

That local extinctions are a normal and inevitable part of ecosystem dynamics is not an item of debate in serious scientific circles, a fact not always fully appreciated by conservation practitioners. Indeed, there is now an impressive amount of literature on extinctions from fragments. For example, an important result from long-term experiments on forest fragmentation in Amazonia shows that while smaller patches of forest have higher extinction rates of birds than larger ones, the actual extinction rates of even the largest patches are surprisingly high.¹³ Indeed, some are so high as to suggest that the only acceptable size for a biological preserve

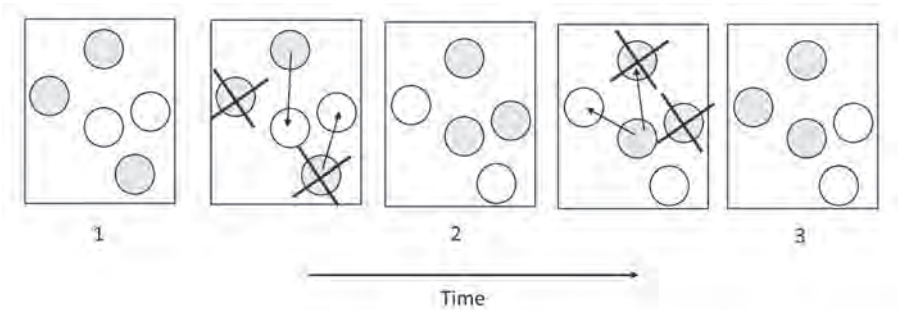


Figure 2.3 *Diagram of metapopulation dynamics*

Note: Each circle represents an individual habitat that is either occupied (shaded) or not (unshaded) by the organism in question. Between time 1 and time 2, two habitats experience extinction (the Xs indicate that the population completely dies out in those two habitats), and two previously unoccupied habitats become occupied through migration. Between time 2 and 3, again two habitats experience an extinction, and two migration events occur, but this time one of the habitats that experienced an extinction was also recolonized. Note that at all three times, the proportion of habitats occupied is 0.67 (three out of five), even though no individual habitat remains occupied.

Source: The authors

is one that is far beyond reasonable expectation. A similar example comes from the long history of the National Park Service in the US, arguably the country with the best-developed national park system in the world. Tabulating observed mammalian extinction rates for biological preserves in North America, a dramatic increase in extinction is found as the size of the park decreases. But more importantly, the largest national parks were not immune to extinctions, even though, as expected, the smaller parks had higher extinction rates.¹⁴ Many other examples could be cited.

A particularly interesting example comes from work done on reptile species on islands in the Aegean Sea.¹⁵ As is always the case, the number of species is correlated with the size of the island. However, in this particular case the geological history of the islands is well known and the authors were able to discriminate between the part of the pattern due to local extinction events and that due to the particular position of the island with respect to mainland source areas. Their analysis convincingly showed that the pattern of species diversity on the islands was completely due to extinctions – extinctions were larger on smaller islands. Here, as elsewhere, local extinctions are a normal and inevitable part of ecosystem dynamics.

As we come to understand the way the diversity of trees is maintained in forests, and extrapolate that understanding to other organisms, it is perhaps not all that surprising that local extinction rates are so high. As an example, ecologist Steve Hubbell, in his recent book, postulates

that one key factor in maintaining tropical tree diversity is recruitment limitation (or failure to disperse to suitable habitat patches).¹⁶ Long-distance dispersal events, under Hubbell's formulation, are important in maintaining species diversity. Therefore, as observed in the examples above, fragmenting the forest and consequently limiting the rare dispersal event from point x to point y in the original spatially extended forest is likely to cause local extinctions and a concomitant reduction in regional biodiversity. Unfortunately, such expected extinctions are likely to occur far into the future, making the political case for conservation here and now particularly difficult.

The landscape mosaic

So far we have presented the theory of metapopulations in its most elementary fashion. Applying the theory more directly to fragmented landscapes we have 'natural habitats' embedded within an agricultural matrix. Local extinctions occur in the patches of natural habitats but they are counteracted by migration from other patches. The migration occurs through the agricultural matrix, with some types of agriculture promoting more migration than others. The implicit assumption here is that the matrix, although potentially of variable quality, is homogeneous (that is, homogeneously good, intermediate or bad). With some exceptions, this is almost never the case (Figure 2.4).¹⁷ In this section we explore the more realistic situation where the landscape is composed of a mosaic of habitats of varying quality, including fragments of native habitat.

Suppose that we categorize habitat types in order of their quality, either in terms of biodiversity directly or in terms of their migratory potential (or permeability). A matrix is then composed of a collection of habitats of various qualities, and the quality of the matrix is effectively the sum or average of the qualities of the habitats within it. In Figure 2.5 we abstractly illustrate four matrix categories.

Thus the qualities of each habitat type somehow combine to make a matrix either conducive to migration or not. From the point of view of landscape planning, in the case of either stepping stones or corridors, the basic question is one of the probability of connecting the two forest fragments. For example, if the probability of an organism migrating out of a low-quality habitat (the lightly shaded habitats in Figure 2.5a or b) is zero, and assuming that the organism can move only to an adjacent square, then the probability that the organism could travel from one forest fragment to the other in Figure 2.5a is zero. On the other hand, that probability (that an organism could travel from one forest fragment to the other) is 1.0 in the case of Figure 2.5b, since all the high-quality habitats are connected. It is an interesting mathematical exercise to find out the probability of a pathway existing from one patch to the other (which is equal to the probability of an organism travelling from one patch to the other), given a random allocation of high-quality patches in the matrix (Figure 2.5a). It turns out



(a) A homogeneous landscape dominated by maize monocultures in midwestern US.



(b) Maize as a component of a landscape mosaic, with surrounding patches of vegetables, fallow lands and forest, in Chiapas, Mexico.

Figure 2.4 *Two types of landscape mosaic*

Sources: (a) Taylor Davidson; (b) John Vandermeer

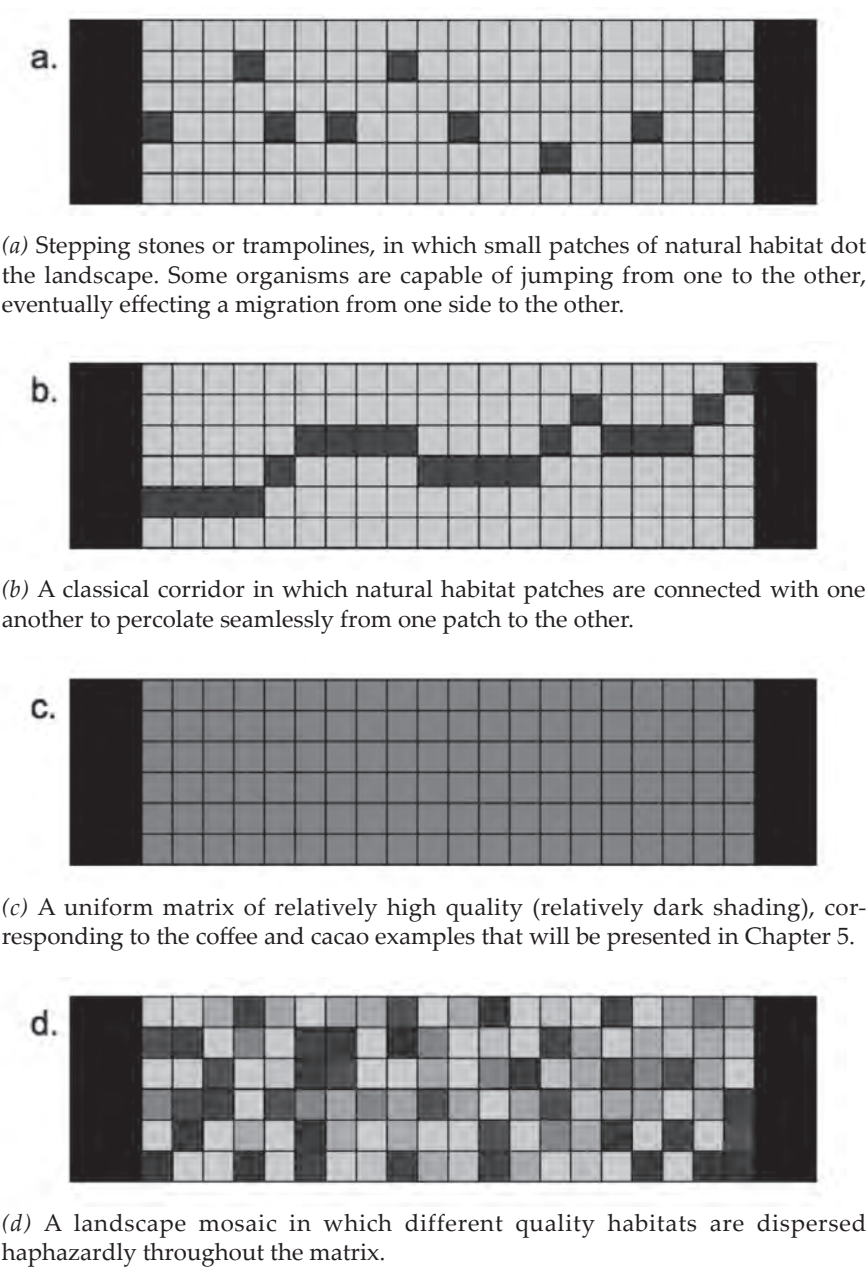


Figure 2.5 *The various types of matrix that connect two forest fragments*

Note: The fragments of natural habitat are the black rectangles at the two ends of each of the four cases. The shading indicates the quality of the habitat type: the darker the shading, the higher the quality.

Source: The authors

there is a threshold effect where the probability goes from virtually zero to virtually 1.0 at a density of high-quality habitats of 41 per cent (below 41 per cent the probability of connecting the two forest fragments is close to zero and above 41 per cent it is close to 100 per cent).¹⁸

Why the figure is exactly 41 per cent is somewhat difficult to explain, but the basic idea is evident from the spreading-forest-fire model.¹⁹ Think of the black squares in Figure 2.5d as individual trees in a plantation, the canopies of which touch one another only if the squares themselves touch. If you set a fire in the left patch, the question is how dense the tree plantation has to be for the fire to spread through the matrix to the patch on the right. Assuming that the trees are planted randomly in the plantation, with two or three trees it is obvious that the fire will not spread. With almost all the positions occupied by trees it is obvious that the fire will spread. But what will be the pattern as the density of the trees increases from zero to 100 per cent. It turns out that once the density reaches 41 per cent it is almost certain that there will be a pathway that allows the fire to percolate from one side of the plantation to the other. The important point is not the precise figure, but rather that there is a threshold, a percolation threshold, at which the probability of percolation jumps to almost 1.0. Using this formula, we see how there is a metaphorical connection between the so-called percolation threshold and the idea of a corridor.

When the sub-habitats in the matrix are neither perfect natural habitats nor completely 'poisonous', but rather of some intermediate quality, the fundamental question to be asked is different. Rather than the probability of percolation (probability of an effective corridor, which is the same as the probability that an organism *could* travel from forest fragment to forest fragment), we ask what is the probability that a dispersing organism *does* travel from fragment to fragment, which is a function of every possible pathway in the matrix. Thus, for example, in Figure 2.5c there are 20 columns of habitat that need to be traversed in order to migrate from one forest fragment to the other. If each of the squares has a probability of 0.95 that an individual entering will successfully migrate through the habitat, the probability of getting from one fragment to the other, for any individual moving in one direction, is $0.95^{20} = 0.36$. In other words, for every 100 individuals trying to migrate from one fragment to the other, 36 will be successful.

The situation becomes a bit more complicated when the matrix is a landscape mosaic.²⁰ Each possible pathway has a distinct probability, as illustrated for an extremely simple example in Figure 2.6. For individuals that randomly disperse, the average of those distinct probabilities (average of all possible pathways, not just two as illustrated in Figure 2.4) will be the probability of dispersing from fragment to fragment.

It is thus evident that the landscape mosaic is conceptually distinct from the stepping stone or corridor idea. In the case of stepping stones or corridors, the interesting question is 'what is the probability that a pathway exists between the forest fragments?' In the case of a landscape

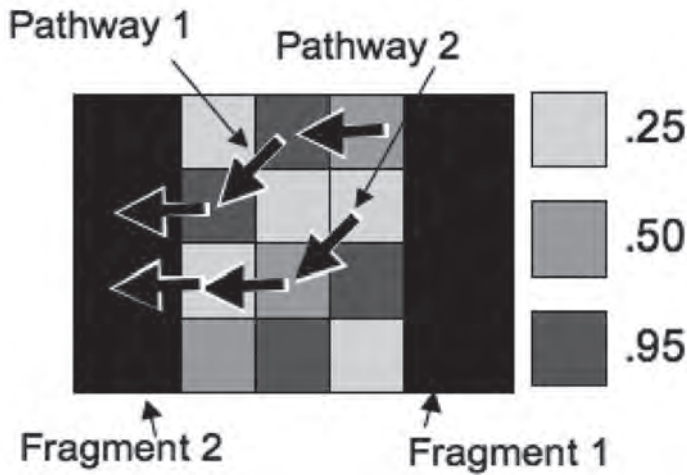


Figure 2.6 *Extremely simplified landscape mosaic in which the matrix between two fragments is composed of three types of habitats*

Note: Shading indicates probability of migrating out of that habitat type. Probability of migrating from fragment 1 to fragment 2 is $0.50 \times 0.95 \times 0.95 = 0.45$ for pathway 1, and $0.25 \times 0.50 \times 0.25 = 0.03$ for pathway 2.

Source: The authors

mosaic, the basic question is ‘what is the probability of migration from fragment to fragment?’ The answer for stepping stones or corridors will be either close to zero, or close to 1.0. The answer for a landscape mosaic will be some figure between zero and 1.0, but not restricted to one extreme or the other.

It is evident with this particular formulation that the habitat with the lowest quality is likely to have an especially strong effect on the overall quality of the matrix. For example, a habitat type that receives a large dose of biocides at regular intervals, such that any insect entering that habitat is almost sure to die, will act as a major impediment to the migration of insects from fragment to fragment. Thus, even though it is the landscape as a whole that determines the overall migration rate, it is still the case that the qualities of individual habitat types are important and worthy of much attention in whatever planning programme is involved, whether the anarchic mode of the neo-liberal economic model or some more organized planning. As we move to integrate more design into landscape ecological research,²¹ formulations that better reflect the complexities of human altered landscapes could be helpful.

For most agricultural landscapes, especially in the tropics, there is ample evidence to suggest that the mode of production can determine various degrees of habitat quality with respect to biodiversity.²² For example, in tropical rice fields on the island of Java, an experimental study

confirmed the expectation that so-called autonomous biological control in rice exists in a landscape mosaic that included habitat heterogeneity. Of particular importance is the fact that a large number of insect species feed on plankton and detritus within the rice fields themselves.²³ Any procedure that reduces plankton in the rice paddies (e.g. pesticides) will increase the effective extinction rate in that field. Not surprisingly, maize fields treated with insecticides have lower insect biodiversity than organic fields,²⁴ and cereal fields managed organically generally have higher weed species diversity than conventional fields.²⁵ Some of these examples will be explored in more depth in Chapter 5.

ECOLOGICAL THEORY AND POLITICAL REALITIES

Conventional wisdom has it that the natural habitats of the tropics have been devastated. Who can be against conserving the ones that remain? Yet, as we argue in great detail later, the simple loss of habitat is only a very small part of the problem. It is true that much of the original forest and savannah cover of the terrestrial parts of the tropics has been dramatically altered since European invasion and colonization. But in the vast majority of cases that alteration has not been absolutely complete. The impressive scenes of devastation so common on conservation websites are actually not as widespread as one might think. In fact, as agricultural frontiers open, forests and savannahs are cleared as needed, and as technology and topography allow. The consequence is that much, perhaps most, of the tropics can be characterized not as 'deforested' but rather as 'fragmented' (Figure 2.7).

Anticipating a more detailed analysis and case studies (Chapters 3–5) we here note that this pattern of fragmentation has created a landscape that, viewed through foggy lenses, looks a lot like an archipelago of islands in the ocean. But here the islands are fragments of forest, savannahs or other natural ecosystems in the ocean of agricultural activities. A real conservation programme cannot ignore this reality! Even as the world struggles to protect the few remaining large areas of tropical habitats from further exploitation, we must acknowledge that a large fraction has already been exploited and that perhaps most of the world's biodiversity is located not in those few remaining protected natural areas, but in the far more extensive landscapes in which thousands of islands of natural habitat exist in a matrix of myriad agricultural activities. Our purpose in this book is to examine exactly what must be done in such a situation, if biodiversity conservation is to be successful in the long run.

If habitats are generally like islands in an archipelago, we are naturally led to ask whether it would be possible to treat the ecology of those islands as we would treat real islands. And here the body of ecological theory described above can be brought to bear on the problem. As a normal

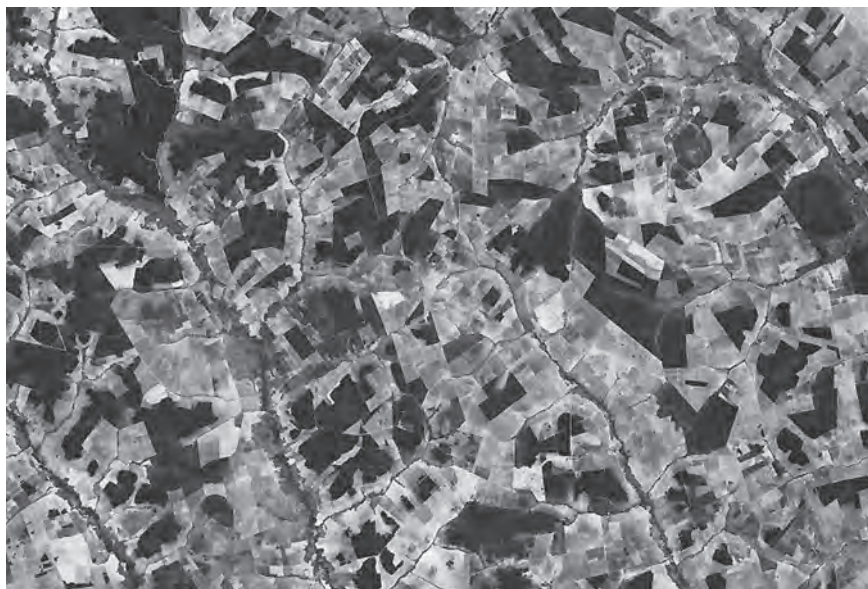


Figure 2.7 *A fragmented landscape near Campo Grande, Brazil*

Note: Darker areas are remnants of natural vegetation embedded in a heterogeneous agricultural matrix.

Source: Google Earth

part of the theory of island biogeography, the biodiversity on any given island is proportional to the rate of immigration of new species to that island divided by the rate of extinction on that island. We emphasize that extinction at a local level is a perfectly normal process, one that can be seen, albeit using subtle clues, on many islands and in many fragments.²⁶ But even though species become extinct regularly on individual islands, they are rescued from becoming extinct over their entire range through migration among the islands.

This picture, a picture accepted as prevailing wisdom amongst ecologists today, has extremely important consequences for biodiversity conservation. In a landscape that has already been fragmented, we face an island-like situation. For biodiversity conservation we must be concerned with the extinction rate and the immigration rate. The prevailing wisdom amongst many conservationists is that the political agenda is uniquely determined by the need to protect remaining natural habitats, which is to focus on the islands in the landscape. For the most part, the extinction rate on an island is determined by the size of the island, smaller islands having higher rates of extinction than larger ones. And the critical fact we wish to drive home is that there is not much we can do about local extinction rates, given a fragmented landscape. Thus, protecting the remaining patches

of natural habitat is certainly an important component of a conservation programme, but it is not nearly enough! Fixing the landscape at a particular level of fragmentation means fixing the extinction rates at a particular level. Nothing beyond preserving the patches of natural habitat can help in lowering extinction rates, if indeed local extinction is strictly a function of patch size.²⁷ Extinction is a normal biological process and will go on no matter what we do.

We need remain mindful of the fact that extinction is only one side of the biodiversity equation. The other side is immigration. And immigration rates are indeed something we can do something about. Immigration rates are set by what happens in the 'ocean', which is to say in the matrix within which those habitat fragments occur. And for the most part, at least in the areas of the globe that are currently tropical, the 'ocean' is an agricultural matrix. This means that the type of agro-ecosystem we allow to exist in the matrix will determine the immigration rate to the islands of natural habitat. This elementary fact about the ecology of biodiversity has enormous socio-political consequences. It means that a serious conservation programme should focus on the type of agriculture practised within the matrix, rather than on what happens solely in the fragments of natural habitat.

Completing the general picture, we note that promoting a high immigration rate means focusing on the agro-ecosystems, which in turn means examining what is happening socio-politically in the agricultural matrix. This apparently unavoidable conclusion brings us face to face with the political turmoil that occurs today in the agricultural sector of the tropical world. Ignoring that turmoil is ignoring the only part of the biodiversity question that matters in a practical sense: the immigration rate.

NOTES

- 1 May (1988); Erwin (1982).
- 2 Wakeford (2001).
- 3 Very small, relatively unorganized cells are called prokaryotic. Much larger cells with a great deal of internal organization are called eukaryotic.
- 4 Gould (1990).
- 5 Palmer (1994).
- 6 The ecological niche of an organism is its role within the ecosystem and all the required resources and characteristics needed for that organism to survive.
- 7 MacArthur and Wilson (2001).
- 8 McNeely and Scherr (2003). This figure includes only agriculture, pastures for livestock production, tree plantations and urban areas. It does not include fallow areas, secondary forests or forests that are used and managed by humans.
- 9 Perfecto et al (1996); Greenberg et al (1997).
- 10 Hubbell (2001).
- 11 Levins (1969).
- 12 Hanski and Gilpin (1991).

- 13 Ferraz et al (2003).
- 14 Newmark (1995).
- 15 Foufopoulos and Ives (1999).
- 16 Hubbell (2001).
- 17 A close-to-homogeneous matrix can be encountered in areas dominated by a particular type of crop, for example, the banana growing region of the Atlantic coast of Costa Rica, where a single banana plantation can extend for tens of thousands of hectares (Vandermeer and Perfecto, 2005a).
- 18 Vandermeer and Perfecto (in preparation).
- 19 Turcotte and Malamud (2004).
- 20 Vandermeer and Perfecto (in preparation).
- 21 Nassauer and Opdam (2008).
- 22 Swift et al (2004).
- 23 Settle et al (1996).
- 24 Dritschilo and Wanner (1980); Perfecto (1990).
- 25 Hyvönen et al (2003).
- 26 Bolger et al (1991); Fisher and Stöckling (1996); Brooks et al (1999); Kerry (2003); Rooney et al (2004); Matthies et al (2004); Williams et al (2005); Helm et al (2006).
- 27 Here there is a legitimate question as to how the matrix may actually affect extinction rates. Some authors have suggested that larger migration rates can actually reduce the extinction rates within islands or habitat fragments (Brown and Kodric-Brown, 1977). We more or less accept the more classical idea that local extinction rates are only a function of the size of patches.

The Agricultural Matrix

01

n Cauwelaert

The general argument of this book involves agriculture. Since almost all terrestrial ecosystems are now fragmented, resulting in the likelihood that most species are forced into a metapopulation structure, the areas between fragments will determine the degree to which organisms migrate from fragment to fragment, and thus their survival probability. Those areas between the fragments are composed, to a great extent, of agro-ecosystems. Thus, any serious conservation effort must have at least part of its focus on agro-ecosystems. Within that focus we ultimately conclude that the industrial agricultural system is not nearly as likely to provide the high-quality matrix that is necessary for effective conservation as small, farmer-based sustainable systems. Because our argument is so dependent on this agricultural component, we present an in-depth elaboration of precisely what that industrial system is, what the alternative is, and where both came from. The following sections provide that background.

THE DEVELOPMENT OF AGRICULTURE

Pre-industrial agriculture

02

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Worldwide, many non-industrial agriculturalists still practise an agriculture that may be similar to that practised by early agriculturalists, variously referred to as 'slash and burn' agriculture or shifting agriculture.¹ This form begins with the felling, or slashing, of natural vegetation. The slashed vegetation dries and is subsequently burned, eliminating much of the vegetation which otherwise could have formed a weed community. Into the nutrient-rich ash-covered ground the desired crops are planted and usually grow vigorously, at least in the first year. The next year, or sometimes sooner, the accumulated post-harvest vegetation is burned, and crops are planted again. In this annual cycle, crop production declines each year, due to a reduction in soil fertility, accumulation of pests, and a variety of other factors. Crop production eventually declines to unacceptable levels, and the field is left fallow. The consecutive number of years in production varies widely, as does the time necessary to leave the area fallow, depending on local ecological, cultural and socio-economic conditions.

3-4

2 notes:

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During the fallow period, enough time is needed to replenish the soil nutrients and organic matter, eliminate whatever disease agents have built up in the soil and to develop the vegetation that once again

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will permit fire to eliminate weeds – generally, fire-resistant plants are eliminated by higher, more woody vegetation through the process of ecological succession. Another relevant factor is the size of the local human population and its food requirements, since that will dictate how much land must be put into production at any given point in time,

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which indirectly establishes a limit on the length of the fallow period. For example, if a total of 100 hectares is in the land pool, farming one new hectare per year permits the potential of a 100-year fallow period, while farming 10 hectares per year permits the potential of only a 10-year fallow period. Contrarily, the intensity of production itself determines, to some extent, the number of people needed to maintain that level of productive activity. That is, there are two relevant population densities that need to be considered: the number of people necessary to make the production–fallow cycle function and the number of people that production–fallow cycle will support.²

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It is worth noting that in the contemporary world there is a form of ‘slash and burn’ agriculture that differs substantially from more traditional forms.³ The more traditional form is usually adapted to local conditions with fallow periods that are long enough to permit the recovery of the ecosystem before entering a new crop cycle, thus making it sustainable over the long term.

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The traditional form is also frequently associated with land tenure arrangements that provide some level of security over land use. Contrarily, recent migrants into a new area sometimes practise what is also called ‘slash and burn’ agriculture, but with less than perfect knowledge of local ecological forces, a shorter fallow period, techniques that are not conducive to sustainability, and little or no land tenure security.

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It is useful to distinguish between this migratory agriculture that uses ‘slash and burn’ techniques and traditional ‘slash and burn’ agriculture, which is arguably more sustainable. Traditional ‘slash and burn’ has a particular territory in which the farming family or farming community operates; the fallow lands are treated as part of the agricultural system; and only rarely is virgin vegetation cut. In contrast, migratory agriculture involves the cutting and burning of whatever vegetation is on the land, frequently old-growth forest at the edge of the agricultural frontier, clearing the land as long as it's productive, and then moving on to new land, causing fragmentation and deforestation.

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A characteristic of traditional ‘slash and burn’ that is often not fully appreciated is the care and attention given to each phase of the agricultural cycle. A striking example of high-level management is the tradition of *mal monte* and *buen monte* (bad weeds and good weeds) developed by the Mayans of southern Mexico.⁴ Farmers actively observe their fallow land, and have a detailed knowledge of the sorts of wild plants that invade, recognizing some as harmful to the overall agricultural system, but others as beneficial. Sometimes farmers will actually weed out ‘bad’ plants from the fallow land and plant good ones. Exactly what makes some plants good and others bad is not always obvious. When asked why particular

plants are good, farmers frequently answer 'they make the soil healthy,' or 'it is easy to cut'. Legumes are usually considered good plants and one can speculate that the underlying ecological mechanism is nitrogen fixation. Spiny vines are usually regarded as bad, probably because they are annoying when cutting the vegetation during land preparation. The important point is that the fallow land itself is not just land that is left idle for Nature to take its course, but is thought of as a regenerative part of the agricultural cycle.

Managing the fallow cycle is just one example of the sophisticated technology, based on underlying ecological knowledge, that is frequently employed in these more traditional systems. Furthermore, 'slash and burn' agriculturalists and other more traditional farmers are excellent experimentalists, always trying out new techniques, new varieties, new crop combinations and so forth. Even though their farming methods are steeped in tradition, that tradition is flexible, and actually includes innovation. Such an attitude is of obvious importance when searching for alternative ways of doing things. Local farmers may not understand the terms used by the academic ecologist or, for that matter, the rural sociologist, but their understanding of the natural world and the society around them is deep. Above and beyond the obvious ethical imperative of incorporating stakeholders into any development plan, ignoring the knowledge base of local farmers is simply bad science, as well as bad politics. Fortunately, the importance of local knowledge is now being recognized by the international community as exemplified by the recommendations of an intergovernmental agricultural assessment concluded in 2008.⁵

The evolution and domination of European agriculture

We can think of the year 1492 as a watershed in the story of how agriculture has transformed the face of the Earth. When Columbus stumbled on the Americas he unleashed a process of profound change that was as important for the biology of the Earth as it was for the history of human society. We can also use the date as a rough marker of the start of another related process of change that was to be just as profound for the fate of the biological diversity of plants. Europe was not only poised to reshape the Americas and Africa and much of Asia through imperial expansion and trade, but Europe was itself beginning to change its own ways of using the land and its resources. These changes, in turn, would be exported to the rest of the world where European colonies were established. Taken together, the European encounter with the Americas and the new ways Europe began to use its land would have enormous effects on the relationship between agriculture and biodiversity.

At the end of the 15th century, many regions of Europe were already beginning to see changes that would become steadily more dominant over the following five centuries. As seen in the landscape, fields and pastures

were becoming larger. More of the land was being used to produce goods to be sold in cities and transported relatively long distances, rather than being consumed by those who produced, sold or bartered them locally. The conversion of forests to pasture and cropland accelerated. Concomitantly, those who worked the land began to be paid wages rather than produce as part of a complicated system of serfdom that granted serfs access to land in return for a series of traditional obligations to their lords. Nobles had traditionally regarded their land as a source of power and prestige, treating their forests and marshes as reserves for hunting pleasure, hunting itself being thought of as a peculiarly noble activity that both signified power and granted prestige. As the European economy changed, the nobility began to wonder if they could make better use of wild places as sources of cash in the new economy of trade and manufacturing. In particular, the manufacture of textiles had become the leading edge of a technological frontier of industrialization, and those who controlled land began to see more value in it as a way of producing saleable wool in the newly forming economy of money. The nobility that failed to sense the power of the changes underway were often pushed aside by urban entrepreneurs who had a better understanding of the new role the land was coming to play. In short, agriculture was becoming capitalist agriculture.⁶

The process was self-reinforcing. The production of wool required less labour per unit of land area than the production of food crops. In England, a set of legal changes, known as the Enclosures, were designed to push peasants off cropland. The Enclosure movement and similar events elsewhere in continental Europe generated conflict and violence over roughly two centuries as peasants were forced to relinquish land used for their sustenance so that it could be used to provide wool for manufacturing. Textile manufacture required workers – and at this stage of primitive industrialization, it required a lot of workers to produce any quantity of cloth. Increasing numbers of people worked in manufacture, trade and transportation of goods, while at the same time cropland, forests and marshland were converted to sheep pasture. Consequently, demand grew to produce more food on less land and with less labour. Those who could grow more food were rewarded with increased income. Furthermore, as trade grew there was more demand on forests for wood to make boxes, barrels, wagons and ships. As cities grew, more wood was also needed for houses and other buildings, and great quarries and mines were cut into the earth to provide a vast range of materials.

For a long time, the changes in the use of agricultural land use and the more intense use of forest products was largely localized and haphazard. But by the 18th century, people began to speak of 'scientific agriculture', seeking a systematic approach to the problem of feeding more people with less available cropland and fewer farmers and farm workers. By the 19th century, the term 'scientific forestry' came to describe attempts to increase the amount of forest products the land could produce. Similar self-conscious efforts to use the land more intensively grew up on the

European continent. Inventors, entrepreneurs, scientists and farmers began applying new scientific and technological advances to the problems of maintaining or enhancing soil fertility, making tools more durable and efficient, providing better drainage and irrigation, selecting and breeding crops and animals that would yield more, and improving transportation and motive power.

While all this was occurring, the European settlement of the Americas provided both a stimulus and an outlet for making agriculture both more capitalist in nature and more intensive in its use of land and labour. Several decades before Columbus's voyages, the Portuguese were already experimenting with growing sugar on islands off the west coast of Africa. They found it profitable to capture or buy slaves in Africa to plant large fields with the single crop of sugar cane, a crop which, at that point, brought fabulous prices as a luxury good sold in Europe. The model of the large plantation specialized in a single crop and cultivated with forced labour would come to transform regions in the Caribbean, in much of North America, in Central America and much of South America. Sugar, cotton, tobacco, and later, coffee, cacao and banana plantations were great engines of social and biological change. In most places, monocrop plantations replaced tropical and subtropical forests of enormous biodiversity. For example, all along the northern and central coast of Brazil, planters destroyed a great swathe of the Atlantic Coast rainforest, or *Mata Atlântica*, to plant sugar cane. Later, in the 19th century, the coffee boom in Brazil would nearly finish the job of destroying Brazil's Atlantic Coast rainforest, perhaps the most diverse in the world. Plantation owners did the same in much of the Caribbean and parts of Mexico and Central America and in the south of the US. Most of the forest would simply go up in smoke, but a significant amount of wood went to further fuel European expansion by providing dye-woods, ship timbers and building lumber for new cities in the Americas and for the old, rapidly growing cities in Europe. Although some crops have been displaced by others, tropical monocrop plantations continue to this day to advance further deforestation and/or prevent regrowth of forests throughout the tropics.⁷

As they devastated the forests and other natural habitats of the Americas, plantations also had powerful indirect effects on European agriculture. Some of the money earned from American plantations was invested in hurrying forth the changes in industry and agriculture that were reshaping the European landscape. Plantation products from European colonies were among the most important items in the growing world commerce and provided essential food and materials for European economic growth. In addition it is notable that the plantation system formed a model for agriculture as an economic enterprise that assembled masses of labour and large expanses of land for profitable exploitation. Such plantations were not new to Europe – the Romans had used a comparable model – but the American plantation revived the form in the specific context of the rapidly expanding and increasingly technological capitalist economy of Europe.

Greater attention would be paid in Europe to the possibilities of replacing small-scale, diverse farming operations with large agricultural estates that would specialize in one or a few crops. In turn, inventions such as the steam engine and railroad would bring about greater and more ambitious changes in the Americas and across the globe.

Confronting declining soil fertility

A central challenge for agriculture has always been the maintenance of soil fertility. In the medieval world, those who worked the land maintained fertility through a number of techniques: crop production was physically close to and integrated with raising livestock and draught animals, so the manure from animals was relatively easy to return to the land. Crop rotation and rotation between grazing and crops was routine. Nutrients were acquired from the seas in many areas by harvesting seaweeds and other marine organisms and incorporating them into cropland. Leaf litter from the forest floor was composted with other plant waste materials. Wood ash, bones, shells, lime and other minerals were used as soil amendments. Human waste was sometimes used in the fields. The relatively small scale of farms and fields, and the integration of animals, crops, forests and fisheries facilitated all of these techniques. The work of the whole family was applied to the multitude of tasks, and in many areas cooperative work among families and villages was common and essential. Demands on the fertility of the soil were limited by supplementary food from hunting, fishing and gathering of wild plants. The whole system only had to provide for the self-sustenance of farming families, plus some additional food for a relatively small number of people who were not directly engaged in agriculture. It was a system strongly based on the mutual interdependence of agriculture, pasture and forest. These elements were usually further integrated with streams, lakes and the sea.

The so-called 'Norfolk four-course rotation' is an example of this system. In the first year, a root crop was sown. The second year would be oats or barley, followed in the third year by a legume (usually clover), and finally, in the fourth year, wheat. Sheep were usually pastured within the system, consuming crop stubble and cover crop (e.g. clover), and, as a matter of course, recycling the nutrients by directly depositing manure in the fields. Most of Central Europe used some sort of three or four-field system, usually with two cereals (e.g. oats and wheat) alternating with a legume, and sometimes pasture.

To this day, everywhere, even in Europe and North America, some elements of these rotational systems survive. Many of the techniques are now being rediscovered and adapted for modern organic and other alternative types of agriculture, a point we emphasize later as part of the overall thrust of our argument about conservation.

In addition to the development of complex rotational systems and the application of various soil amendments, one of the most important

approaches to the problem of soil fertility was the opening up of new agricultural lands. By seizing vast new territories, Europeans were effectively able to acquire soil fertility to provide the agricultural needs for the new world economy that they were constructing. In North America, Argentina, Brazil and Australia, for example, Europeans were able to bring into production vast areas of very rich soils that had never before been cultivated. The accumulated fertility of virgin soils, due to the biological interaction of perennial grasses and trees with the mineral substrate, was perhaps as important to the emergence of Europe in dominating the world economy as was the gold and silver looted and mined from Peru, Mexico, California and Brazil. It provided wealth that ramified throughout the entire world system, including the waves of European immigrant farmers. In addition, Europeans were able to enlist the land and labour of established farming economies of colonial possessions to enrich the European economy. And all of this was accomplished through the subjugation or genocide of the people who had lived in these landscapes until the European conquest.

As the appropriation of the fertility of the world's soils for European purposes proceeded, Europe itself began to experience serious problems of declining soil fertility at least as early as the mid-18th century. This was mainly due to the breakdown of the farming systems that had integrated all the elements of the landscape: cropland, pasture, forest, waterways and the sea. Specialization of most of the agricultural economy in those crops that were most profitable for provisioning growing urban populations, and specialization of individual farms according to local comparative advantages tended to displace the more integrated systems of the past. The land had to be forced to produce far more than the subsistence needs of the farming family and a small marketable surplus. Collecting and spreading animal manure and composts involved longer distances and much greater energy expenditure. Crop rotation and fallow times were neglected or abandoned in order to maximize immediate profits. The important array of wild products from the forest declined with the advance of forest clearing. Perhaps most importantly, on the specialized farms, the old knowledge of how to adapt and how to integrate the various elements of Nature in a system capable of maintaining fertility was often lost. In many areas, as it was lost, it was also scorned as quaint, old-fashioned and useless – a mere relic of the illiterate peasantry who had to be displaced by more 'advanced' and 'scientific' farmers and estate managers.

The new farmers and estate managers to some extent became agricultural experimenters in the new kind of more specialized and intensive crop systems that were taking over. Declining fertility was both a private economic problem for agriculturalists, and a public concern of society interested in maintaining food supplies for growing and ever more urbanized populations. In the 18th century, in search of private wealth and public welfare, various kinds of non-farming scientists, academics, inventors and entrepreneurs began to investigate the problem of soil

fertility and how it might be solved. A good deal of work was done to attempt to make composting cheaper and more manageable for the large and specialized farm. People began to experiment with new combinations of soil amendments of various kinds, including lime and mineral supplements. By the mid-19th century, experimenters began applying the impressive scientific advances in chemistry to the problem of plant nutrition.

A key conceptual breakthrough occurred in 1840 when Justus von Liebig articulated what has come to be called Liebig's Law of the Minimum, in which he recognized that nutrients were required by plants in specific proportions.⁸ Thus a single nutrient in short supply would prevent plant growth. The nutrient that was limiting was the one that was at its 'minimum' with respect to plant growth.

The Law of the Minimum led to the idea that still dominates soil management today, that soils need to be provided with specific nutrients, the limiting ones, so as to increase plant growth. While contemporary understanding of nutrient cycling makes this idea essentially anachronistic, as we discuss below, the idea nevertheless formed the underlying logic for the development of an industrial approach to soil fertility. Thus, in the mid-19th century, an incipient fertilizer industry arose producing superphosphate through a simple chemical procedure, and importing phosphate rock, guano, sodium nitrate and potassium directly from natural sources. Mainly through the process of producing superphosphate, the fertilizer industry had become the British chemical industry's largest customer by the dawn of the 20th century.⁹ Fuelled by the need for nitrate explosives during the world wars, the industry grew ever larger and became one of the major components of the chemical-industrial complex we see today.

Although early capitalization was based on the production of superphosphate, phosphate was not the major limiting nutrient in agriculture in most temperate areas of the world. As Liebig's Law of the Minimum emphasized, all nutrients would eventually become limiting if agriculture continued its development along the lines required by the developing capitalist system. He was particularly concerned, as were many analysts of his day, with the separation of town and countryside. He wrote emotionally about the ecological irrationality of a system in which the nutrients of the countryside (agriculture) were transported to the city (in the form of food) and then dumped in the local waterways (in the form of excrement), only to create the foul conditions of 19th century European cities, at the same time as it created an ecological crisis in agriculture – something we might consider in today's supposedly more sophisticated world, as we continue pumping agricultural runoff into our waterways the world over.

The use of mineral fertilizers was at least a temporary and partial solution to the problem of declining soil fertility that had troubled Europe since the 18th century. Furthermore, based on imported minerals, sulphuric acid (for the production of superphosphate), guano and sulphate of ammonia (a

by-product of the gas works), the fertilizer industry in Britain was already big business by the turn of the century. By the late 19th century, farmers noticed that soil fertility was declining rapidly in the exceptionally rich soils of the central plains of the US and in other nations where Europeans had settled. At the same time, global demand for food was increasing, and competition among producing regions around the world became more intense. As in Europe, the application of mineral and then synthetic fertilizers became a central practice of agriculture in these regions.

An important breakthrough for the industry was discovering how to synthesize ammonium directly, the most important technique being the Haber-Bosch process.¹⁰ With the new process of ammonia production the fertilizer industry expanded rapidly. An especially important element of this expansion came, not from the needs of agriculture, but from the need for nitrogen-based explosives in World War I. In fact, the world was provided temporary solutions for companies like BASF and IG Farben as overproduction had begun to reduce their profits. The need for large quantities of explosives on all sides of the conflict was a godsend for the chemical industries of all countries involved. During the inter-war years improvements in technology again created a crisis of excess capacity which was largely solved by World War II. As might be expected, the end of World War II created another under-consumption crisis. This time, the wartime production levels were sustained by the dramatic expansion of industrial agriculture throughout Western Europe and North America in the post-war years, interrupted only intermittently until the present time.

The gradual emergence of the elemental approach to soil fertility, while enabling dramatic increases in production with little appreciation of the complex nature of nutrient cycling in ecosystems, had two negative consequences – disrupting the overall functioning of the soil nutrient cycling system, and pollution of groundwater, waterways and water bodies in general, including the ubiquitous ‘dead zones’ responsible for killing millions of fish and other sea life throughout the world.¹¹ Furthermore, there is nothing in the physics or chemistry of soils to suggest even approximately, that the direct application of low ionic forms is somehow better than more complicated forms, such as are found in compost or other organic fertilizers. Indeed, much analysis associated with the newer forms of more ecologically based agriculture begins with a challenge to this discourse, noting that from the plant’s ‘point of view’ it matters little if its source of nitrogen is directly applied ammonium or ammonium derived from natural decomposition processes.

Plant breeding emerges to serve ideology

Parallel to the increasing use of fertilizers, farmers and the new breed of specialists known as agricultural scientists began to be much more aggressive in selecting and breeding crop plants for higher yields. Plant breeding was often tied in principle as well as in historical time with the

use of mineral and synthetic fertilizers, because newly developed crop varieties often depended on and could make better use of the high levels of nutrients available through the new fertilizer technology. Plant varieties that could produce more wheat or corn per hectare usually required more nitrogen, phosphorus and potassium, and plant breeders began to breed for the ability of plants to use these nutrients more efficiently. In the first half of the 20th century, plant breeders were remarkably successful in creating varieties adapted to the availability of higher levels of these nutrients to produce more grain. Plant breeding and crop variety selection became intimately tied up with the story of soil fertility.

Plant breeders began to reach a limit, however, in their ability to convert inorganic fertilizers into greater yields. Specifically, while the new varieties could convert much more nitrogen into grain there was a point at which increasing applications of nitrogen did not result in higher yield and could even become toxic to the crop. Working out how to raise the ceiling for fertilizer application to gain yet higher yields became a major challenge to plant breeders in the 1930s.

It was more than slightly strange that in the very years when agricultural scientists focused strongly on the need to raise yields of major grain crops, the world was in the grips of the Great Depression, an event caused at least in part by overproduction.¹² These were the years when the US government, and others around the world, began to pay farmers to retire land from production. They were the years when pigs and other livestock were bought up by the government and were buried in great trenches to keep them off the market. Farm families abandoned the land in great numbers even though there was mass unemployment in the cities – there was no point in remaining on the farm if there was no market for the crops. In spite of this glaring contradiction, agricultural scientists continued to work hard on developing crops with higher yield potential that could make use of high levels of fertilizer application.

The argument for continuing to invest money and time in higher-yielding crops continued through the 1940s and 1950s, but in the 1960s it was reshaped to attempt to deal with the contradiction between high yields and low demand. Instead of emphasizing the advantages to richer nations of higher-yielding crops, the newly developing discourse focused on the poorer countries. These nations and colonies, what we call today the Global South, were largely in the tropical and semi-tropical regions of the world, and were under the direct or indirect domination of the richer nations of the North. Here, it was argued, widespread hunger and famine were due to the lack of agricultural productivity. In addition, as the earliest stages of sanitation and public health measures began to bring down death rates in poor countries, there would be a need for ever-increasing food supplies for what would soon become rapidly growing populations. Many of these arguments carried substantial elements of guilt-mongering about the past and emphasized the need for agricultural scientists of richer nations to carry 'the white man's burden' of resolving the problems of societies that

had been profoundly disrupted by colonialism and economic intervention by rich nations. If agricultural scientists could banish hunger through greater productivity then surely all the sins of the past could be forgotten, if not forgiven.

The counter-argument was that hunger and famines were primarily due to injustice and not to the low-productivity of agriculture in those regions. Land and wealth were concentrated in a few hands. The best agricultural land was controlled by local elites and/or foreigners who used it to produce food and fibre for the markets of rich nations rather than for local populations who had little purchasing power. The majority of rural people were not only excluded from the best land but were subjected to a combination of low wages, high land rent (often in the form of share-cropping arrangements), confiscatory taxes, lack of credit and lack of access to technical information and markets. Because the real money to be made in agriculture came from distant and usually foreign markets, the low purchasing power and illiteracy of rural agricultural producers and workers were not a problem to landowners but rather constituted a way of ensuring continued low production costs.¹³ Attempts to change these conditions met determined political opposition by those in control of resources and land. Often, keeping control of land and labour involved every manner of violence, from individual beatings and torture to mass slaughter.

The argument for social justice as the main approach to resolving hunger was not merely academic – it was being put forward by powerful nationalist, socialist and communist movements throughout the Global South. These movements, some with dramatic success, were challenging local power structures and the international world system based on colonialism and neo-colonialism in nation after nation. In China, India and the countries of Southeast Asia, Africa and Latin America, the specialized European-style monocrop plantation was a major symbol of historic and continuing injustice, and the monopolization of the best land for production for distant markets was always a central grievance.

Control of pests

By the turn of the 20th century there were a variety of methods of pest control that had become well established, ranging from strategic rotations to resistant varieties of crops, release of predators and other natural enemies, and others. It is important to note that there was no particular emphasis on any one technique, the discourse of pest management being one of using all methods available, frequently in combination with one another. Farmers tended to view their farms as either healthy or not, almost as if the farm were the patient and the farmer the doctor, with pests and diseases as metaphorical germs that made the farm sick. Maintaining the farm (the patient) in a healthy state was the principal goal of the farmer. The emergence of petroleum-based biocides, and especially the

socio-political and economic realities of World War II, would change all of that.

With the outbreak of war in 1939, governments generally became interested in pesticides as possible biological warfare agents, and a great deal of government-sponsored research into chemical poisons followed. The US was particularly active in biological and chemical warfare research, and as a result came up with a product that would see its application not in war but in the war against weeds, 2,4-D (although later, as a component of the infamous 'agent orange', it would see war service in Vietnam). In 1945, in the US, 917,000 pounds of 2,4-D were produced, and by 1950 the total had risen to 14 million pounds.¹⁴

But the real revolution was the synthesis of the chlorinated hydrocarbon, dichloro-diphenyl-trichloroethane (DDT) in the late 1800s, and the discovery of its insecticidal properties in 1939. It was quickly adopted by British and US armed forces. Tropical diseases, many of which were vectored by arthropods, were more important killers than the enemy in the practice of warfare. Finding effective solutions was a priority of war research, and DDT seemed to provide the solution.

By 1945 other chlorinated hydrocarbons had been developed, and the arsenal of insect-fighting weapons was well established as part and parcel of war preparedness. Germany had made the same preparations, emphasizing organophosphates (e.g. parathion) rather than chlorinated hydrocarbons. World War II had thus created a high capacity for the production of biocides, with the general class of carbamates joining the chlorinated hydrocarbons and organophosphates to make the three major classes of insecticides we know today. Combine that with the herbicides that were originally developed as a by-product of biological warfare research along with further research into nitrate explosives that easily translated into more efficient methods of producing nitrate fertilizers, and the charge could legitimately be made that World War II was the seed that germinated the agrochemical revolution.

The war was a watershed for the chemical industry and a tremendous productive capacity was the result. However, it was apparent that peace would present a problem in that the capacity that had grown so explosively during the war would suddenly become an excess capacity. The industry thus saw that it was due to face an under-consumption (or overproduction) crisis and began searching for a solution. Agriculture was the obvious target. The industry developed some ingenious marketing strategies in post-war US and Europe. With war fever having reached a pitch, the public was especially susceptible to wartime rhetoric. What had originally been an argument that we needed the chemicals to defeat the enemy in war, was easily translated into the need for these chemicals to defeat the new enemy in agriculture.¹⁵ The importance of this advertising blitz cannot be overemphasized. With wartime and especially post-war propaganda, pests came to be seen as enemies to be vanquished. A 'war metaphor'

replaced the previous 'health metaphor' (the idea of maintaining a healthy farm).

The arms in this new war were the new chemical pesticides produced by the same corporations that produced them for the war effort. The wartime-induced productive capacity of the chemical industry was thus saved by changing the attitude towards pests, seemingly subtly, but in the end in such a way as to transform agriculture dramatically. The new metaphor meant that farmers changed from stewards who maintained the health of their farms to warriors who vanquished their enemies on the battlefield of the farm. The consequences were the massive spraying of biocides in the years following World War II.¹⁶

The Green Revolution

In one nation, Mexico, these three tendencies – chemical fertilizers, improved varieties and pesticides – all came together forcefully in the creation of the research programme that would come to be known as 'The Green Revolution'. In the three years before the US entered World War II, the US and its future allies became acutely concerned about a Mexican government that had become serious about promoting land reform. The reform threatened specific US and British investors and presented a then widely admired example to other peoples of Latin America and the world. In addition, the Mexican government in 1938 expropriated and nationalized the oil industry, one of the world's most productive, which had been owned by US and British corporations. Serious attempts to convince the US government to invade Mexico were rebuffed, but the US did become convinced that it needed to do what it could to blunt the force of the Mexican movement for social change. In the 1940 Mexican presidential race, the US supported the conservative candidate who was running against Lázaro Cárdenas, of the Party of the Mexican Revolution. With the help of the US, Manuel Avila Camacho won the elections and undertook various commitments to help Mexico follow a path of economic growth consistent with US economic and strategic interests on the eve of World War II. One of these commitments was a programme of agricultural research.¹⁷

The agricultural research programme explicitly promised to resolve hunger and poverty in Mexico, and the world, by increasing agricultural production. The early researchers focused on the problem that they had been trying to solve previously: how to develop grain crops that could raise the ceiling on nitrogen absorption. If varieties could be developed that would make use of greater quantities of nitrogen fertilizer, yields could increase dramatically. The story of how this was done is intriguing and has been often told. Indeed, US researcher Norman Borlaug, who won the 1970 Nobel Prize for his work, spent decades telling and retelling the story of his work in Mexico in the development of high-yielding wheat. The success in wheat would soon be more or less duplicated in maize, rice and other crops.

The high-yield crops, however, brought with them a variety of problems. They were designed to make greater use of nitrogen fertilizers, which meant that they were also dependent on these fertilizers. Fertilizers would be toxic even to the new varieties if they were not combined with large amounts of reliably delivered water. The densely planted, nitrogen-rich, irrigated plants made an ideal field environment for insect pests and plant diseases. Pest and disease vulnerability were to be solved by heavy reliance on the newly available synthetic chemical pesticides. In most situations, combining all of these elements meant the use of more and more elaborate and expensive machinery, and in many regions it meant the building of vast new networks of dams and irrigation canals. So, what would become the 'package' offered by Green Revolution agricultural researchers and the companies who quickly commercialized their products was made up of newly developed high-yielding varieties (HYVs), synthetic fertilizers, synthetic pesticides and, wherever rainfall was unreliable, irrigation. The nature and requirements of this package would transform agricultural landscapes around the world in the last half of the 20th century and create massive growth in industries manufacturing the seeds, chemicals, irrigation equipment and machines designed to make the package economically viable and technically reliable. It also represented massive profits for what is now a well-established agribusiness sector.

What made this Revolution a 'green' one? After all, fields were green before this revolution in agricultural technology. The point was that the revolution was *not* 'red'. A publicist working with researchers realized that there needed to be an attractive way of summarizing the meaning of the whole package. It was about green plants and crops, but it was also very crucially about a particular approach to hunger. It posited that it was the lack of productive capability, and *not* social injustice that caused hunger and it was increased productivity, and *not* social change that would end it. In nearly every poor nation of the tropics and subtropics where it was adopted, it was posed quite specifically as a technological solution to the social economic and political problem of hunger. It was said to be better than a political solution that would be based on redistribution of land and other productive agricultural assets, mass education and political enfranchisement of the poor. In most poor countries, the aggressive promotion of the Green Revolution began during years when the US State Department and local governments began to worry about the prospects for success of political movements demanding land reform and the redistribution of wealth.

In Europe and the US, what amounted to the Green Revolution package was seen and adopted largely as a continuation of existing trends in agricultural technology. In the US, and later in Europe, the package gave new force to the persistent problem of overproduction that plagued commercial farmers throughout the second half of the 20th century. Every farmer felt compelled to out-compete his and her neighbours in yields, while painfully aware that as each farmer did so, agricultural prices would

continue to plummet. Each drop in price created a new incentive to try to produce more to earn sufficient income to survive. While some countries adopted actual controls on how much a farmer could market, supply control in the US focused on restricting the area of land a farmer could cultivate in major surplus crops. This gave rise to increased intensification on the land the farmer was allowed to use, increasing the amounts of fertilizer, pesticides and water used, and intensifying environmental damage on cultivated land. As a result, surpluses remained an ever greater problem in most years. The US government aggressively promoted food exports, including 'food aid'. Such food aid sometimes did genuinely feed the hungry, but its more important effect was in destroying local markets for many small-scale farmers, most of whom had not benefited from the Green Revolution package, usually because they could not afford to do so. Sometimes they resisted adoption because of the destructive effects the package had on local environments, cultures and communities. As the majority of farm families in the world were excluded from participation in the Green Revolution because they did not have the credit to buy the necessary inputs or access to the high-quality land and water necessary to make it viable, they had to abandon the countryside by the tens of millions. They crowded into cities poorly able to absorb their presence and with insufficient employment opportunities. In many countries, most notably India, they often had to rely on food handouts produced by the richer farmers in their own country or in the US or Europe, whose domination of the market had driven the poor families off the land. In other cases, they went hungry or became chronically malnourished. Around the world, the countryside sent a tidal wave of migrants to cities. It is no exaggeration to say that the Green Revolution was one of the principal forces for drastic social change in the 20th century, perhaps the most important of all. In this sense, it was indeed revolutionary.

As Green Revolution agriculture increasingly dominated agricultural landscapes all over the world, the older-style plantations, with their roots in the colonial era, continued to monopolize much of the best land in the tropics and subtropics. Many of them began to adopt chemical-dependent techniques similar to those developed for Green Revolution grain crops. Almost everywhere, they continued to depend on low-wage agricultural workers. In many places, such plantations went through cycles of relatively high productivity followed by soil exhaustion and the onset of extreme poverty. For example, the cotton and tobacco plantations of 'The Old South' in the US – Virginia, the Carolinas and Georgia – had experienced both phases before the US Civil War, pushing slave plantation agriculture further west to Louisiana and Texas. Some of Brazil's richest sugar plantation areas experienced steady decline due to soil exhaustion in the 19th century from which the regions have not yet fully recovered. Coffee plantations in Brazil left a broad swathe of forest destruction to be followed only decades later by soil exhaustion during the late 19th and 20th century. Beginning in the early 20th century and continuing to the

present, a combination of plantation agriculture and 'modern' chemical-dependent agriculture has left similar destruction across extraordinarily species-rich areas of humid rainforest and savannah in Brazil's Amazon region. As environmentally destructive chemical-dependent Green Revolution agriculture combines with the older cycles of plantation production, much of the tropical and subtropical world (the planet's great reservoir of species) has been impoverished in biological richness, and often in soil fertility and human welfare.¹⁸

Elsewhere, we have written about the enormous, and mainly negative, implications of taking the Green Revolution approach to resolving the problem of hunger.¹⁹ Even so, many observers believe that intensified chemical-based agriculture has had a substantial positive effect with regard to biodiversity. They argue that intensification of production on the best land allowed regrowth of forests and other wild vegetation on more marginal land. As we argue extensively in Chapter 6, this 'land-sparing' argument is at best ill-informed, both from an ecological and socio-political point of view.

THE INDUSTRIAL MODEL

From peanuts to peanut butter

For years, political economists asked why it is that in agriculture we don't see the same process of capital penetration that we see in other sectors of the economy. In other words, why small farms have not been completely displaced and turned into industrialized corporate mega-farms. A partial answer to this question lies in the distinction between farming and agriculture. Farming is the process of turning seeds into harvestable crops with the use of labour, energy and other resources, like land and water. Agriculture is not just farming, but also the production of agricultural inputs and the processing, packaging, transportation and marketing of the outputs. As evolutionary biologist Richard Lewontin said, 'Farming is growing peanuts on the land. Agriculture is making peanut butter from petroleum.'²⁰ When examined in this manner, there is no doubt that capital has indeed penetrated the agricultural sector. However, until recently, farming, the most vulnerable, risky and unpredictable component of agriculture, was left to the farmers.²¹

The post-World War II capitalization of agriculture was accomplished primarily through the substitution of inputs that were generated from within the farm itself, with inputs that were manufactured outside the farm and needed to be purchased. Starting with the early mechanization of agriculture that substituted traction power for animal power, to the substitution of synthetic fertilizer for compost and manure, to the substitution of pesticides for cultural and biological control, the history of agricultural technological development has been a process of capitalization that has resulted in the reduction of the value added within

the farm itself.²² In today's farms, the labour comes from Caterpillar or John Deere, the energy from Exxon/Mobile, the fertilizer from DuPont, and the pest management from Dow or Monsanto. Seeds, literally the 'germ' that makes agriculture possible, have been patented and need to be bought. This stifles, and in some cases even ends, the millenary practice of seed saving and crop improvement by farmers.

The output side of agriculture is not very different. Once the 'product' leaves the farms, it is increasingly processed, packaged, transported, marketed and sold by large corporations. As an example, Figure 3.1 shows the UK wheat bread bottleneck that illustrates how both farmers and consumers are dependent on a few traders, millers, bakers and retailers. Similar bottleneck graphs can be drawn for many other agricultural products.²³

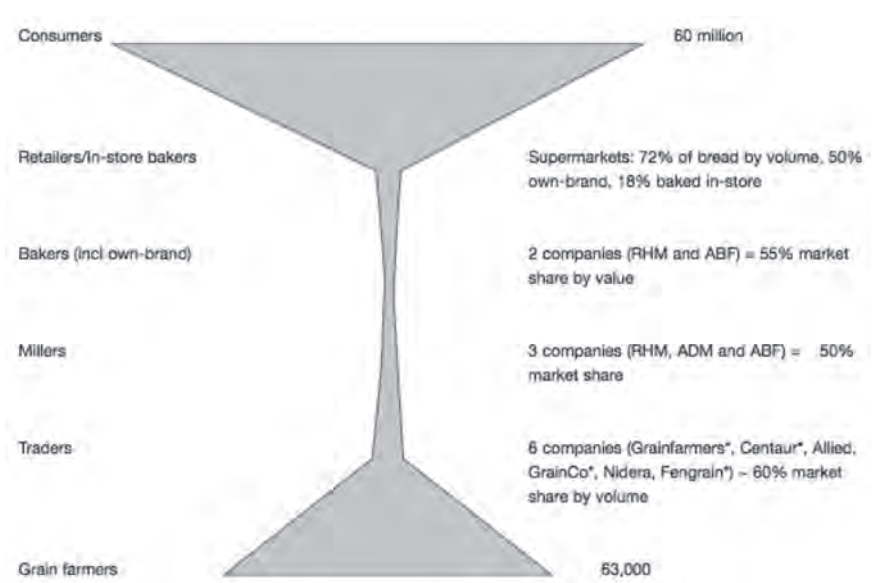


Figure 3.1 *The bottleneck for wheat bread in the UK*

Source: Vorley (2003)

The last 30 years have seen a process of consolidation and vertical and horizontal integration of agribusiness that has resulted in just a handful of corporations supplying farm inputs and buying farm outputs. In Figure 3.2 we present a simplified diagram of the structure of agriculture in the US. The direct producers of food, the farmers, are squeezed between powerful oligopolies (like Monsanto, Exxon/Mobile and Syngenta) that control the prices of farm inputs, and powerful oligopsonies (like Cargill, Continental, ADM and Campbell Soup) that control the prices of farm outputs. When analysed in this fashion, it becomes evident that the billions of dollars in

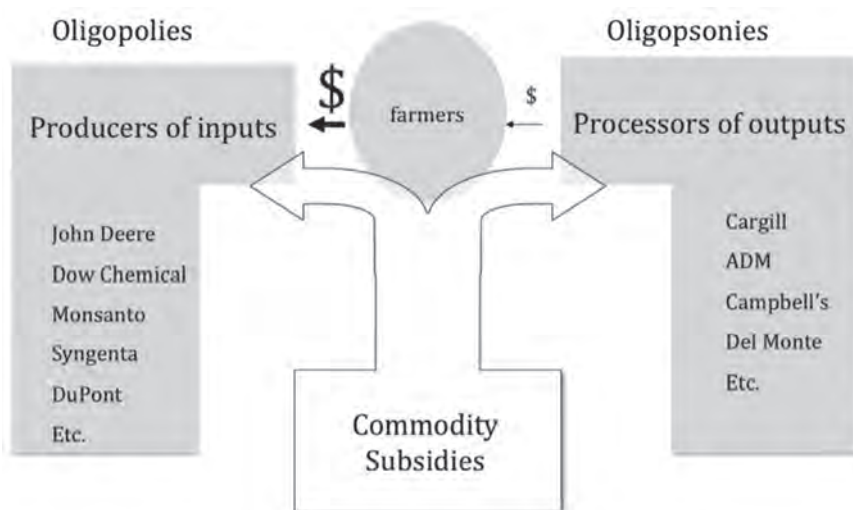


Figure 3.2 *The structure of US agriculture*

Source: The authors

commodity subsidies in the US actually represent an indirect subsidy to corporate agribusiness.

This general structure can be seen in almost any part of the world where agriculture is capitalized. In recent years retailers have also consolidated as megastores, and are playing a crucial role in the commodity chain. For example, in Latin America, by 1993 large supermarket chains already controlled 10 to 20 per cent of food sales, and by 2003 only five corporations were controlling 65 per cent of the sales.²⁴ It is partially because of this structure that the farmers receive only about 10 per cent of what the consumers pay for the food they buy in the supermarkets.

The industrial system in crisis

The view that industrial agriculture has spawned significant problems is hardly contestable, and has become general knowledge.²⁵ The modernization of agriculture included two very general goals: more frequent use of the same area of land (e.g. decrease the time of fallow periods) and increased specialization of productive species (loss of plant biodiversity, usually in the pursuit of higher yields and ease of mechanization). The extended fallow periods of many forms of traditional agriculture were abandoned in order to use the same area of land every year or for continuous production. The increased frequency of resource withdrawal was subsidized with increased use of external inputs.²⁶ The loss of fallow periods and use of chemical fertilizers can lead to loss of soil fertility, in part through disruption of the soil microbial systems, and decreases

in macrofaunal and plant-associated biodiversity.²⁷ The ecosystem functions often provided by such associated biodiversity (e.g. nutrient retention, biological pest control, pollination) are necessarily lost as well.²⁸ Biodiversity in the ecosystem is decreased further when traditional, diverse, locally adapted crop varieties with resistance to native diseases and pests are abandoned and intercropping is halted in favour of high-yield monocultures amenable to mechanized production methods. Furthermore, higher-yielding crop varieties are often less resistant to pathogens and pests, especially given the highly dense and structurally simple concentration of plants, and are more prone to the spread of insect pests and diseases. In the transition from diverse crops and intercropping to monoculture many natural enemies of the pests are lost, increasing the need for pesticide applications.²⁹

*Less diversity, more pests; more pesticides,
less diversity*

The first indication of environmental problems due to this new technology was the publication of Rachael Carson's *Silent Spring* in 1962.³⁰ Carson suggested that the massive use of pesticides was having a dramatic negative effect on the environment. Previously there had been much popular commentary about the human health effects of pesticides, a concern initially brought up by farm workers in the US and shared even by the pesticide manufacturers. But *Silent Spring* was the first popular account of the environmental consequences of pesticides, contributing not only to concern about environmental poisons, but perhaps providing the main springboard for the emerging environmental movement.

What Carson said is now well known, and, in retrospect, not surprising. Pesticides indeed do what they were designed to do: they kill. However, broad spectrum pesticides kill not only the targeted pests, but also many species that are not targeted. The poisonous effects of pesticides and their residues may persist for a long time in the environment. Due to their persistence, pesticides also concentrate in the higher trophic levels, thus making non-lethal doses at lower trophic levels quite dangerous at higher levels. Pesticides stop working when pests evolve resistance to them. These were the basic themes of Rachel Carson's book.³¹

Silent Spring was an extremely well-documented book. Despite a Herculean effort at finding errors, mainly by representatives of pesticide manufacturers, only the most trivial errors were eventually found. Nevertheless, an immense and coordinated attack against the book was orchestrated by the pesticide industry, including an attempt by Velsicol, Monsanto, and indeed the entire chemical industry, to pressure Houghton Mifflin, the publishing company, not to publish the book in the first place.³² Book reviews were generally harsh and, as was later discovered, frequently written by scientists receiving monetary rewards from the chemical industry. As was carefully documented in subsequent works,

most independent scientists received *Silent Spring* positively. Indeed, rereading the book today even suggests that its actual problem was understatement.

Silent Spring raised a great deal of awareness about environmental pollution and propelled the environmental movement in the 1960s. However, the chemical industry has been counter-attacking ever since. Rachel Carson's predictions have come true in many areas of the world, and further problems have emerged. Industrial accidents in pesticide manufacturing plants, plus worker exposure to toxics in such plants have added to her concerns. The environment is now filled with chemicals that mimic oestrogen, causing not only feminization in reptiles, but lowered sperm counts in humans, as documented in the remarkable book *Our Stolen Future* by Theo Colborn.³³ Unfortunately, the final chapter on pesticides has yet to be written. What began with the need to curb an under-consumption crisis has been transformed into an environmental crisis of unprecedented proportions.

While Carson's book was a watershed, a less acknowledged, but equally important book was *The Pesticide Conspiracy* by Robert Van den Bosch, published in 1978.³⁴ This book accomplished three things simultaneously. First, it reinforced all of the analysis of Rachael Carson, sometimes updating information and pinpointing problems caused by pesticides that Carson had not foreseen. In this, Van den Bosch was far more critical of pesticides than Carson had been, partly because 16 more years of research had made more and better data available. Second, it made explicit what Carson had only left for the reader to conclude, that pesticides were being used largely for the purpose of making profits for those who manufacture them, and that the 'conspiracy' involved government and university scientists receiving direct and indirect financial rewards from this industry. Third, it elaborated a generalized mechanism that explained the biological reasons that pesticides came to be such a problem, strongly implying that the problem would continue, and could even become worse. Van den Bosch called this mechanism the 'pesticide treadmill,' and it has since become part of the general discourse of the environmental movement.

The 'pesticide treadmill' includes three forces operating simultaneously:

- 1 Pest resurgence – the fact that a pest will usually come back in force after the pesticide kills not only it but also its natural enemies.
- 2 Pesticide resistance – the unavoidable fact that pests evolve resistance to whatever poison is thrown at them.
- 3 Secondary pest outbreak – the surprising tendency of the pesticide to kill the natural controls of herbivorous insects that were not previously pests (because of those natural controls that had kept them from becoming pests earlier), causing these insects to reach outbreak levels (Figure 3.3).

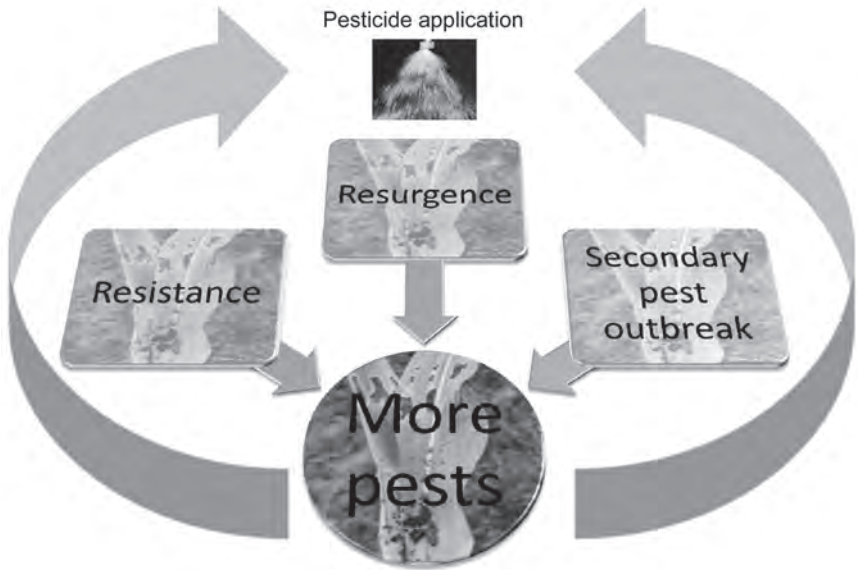


Figure 3.3 *The 'pesticide treadmill'*

Note: The 'pesticide treadmill' results from pests evolving resistance to pesticides; pests resurging stronger after pesticides kill their natural enemies; and other herbivores (that had been kept in check by their natural enemies) becoming pests after pesticides kill their natural enemies.

Source: The authors

Each of these forces had been well known even before *Silent Spring*, but they were first put together as a coherent whole by Van den Bosch.

Putting these three forces together – resurgence, resistance and secondary pest outbreaks – we have a pattern that is devastating in the long run for farmers. A resurgent pest suggests to the farmer that more pesticide is needed since the problem is worse. Because of resistance, the pesticide is no longer as potent as it once was, suggesting to the farmer that more pesticide or stronger pesticide is needed, and the new pests that mysteriously appear suggest once again that more pesticide is needed. It seems much like a drug addiction story. The more pesticide you use, the more you need – hence the name, the 'pesticide treadmill'.

World consciousness of the environmental problems of industrial agriculture grew rapidly after the publication of *Silent Spring*. By acknowledging Van den Bosch's 'pesticide treadmill' and taking some action to curb the most blatant negative effects of pesticides, the horrible environmental consequences envisioned by Carson have been partly averted. Nevertheless, much of her concerns did come to pass. Agricultural areas, such as the San Joaquin Valley in California, are largely devoid of

diversity. A drive through the vegetable-producing areas, for example, is ominously similar to the opening sentences of *Silent Spring*, with the absence of birdsong, the absence of small flying creatures, the feeling of desolation (Figure 3.4). But the casual motorist in the San Joaquin Valley does not really see the whole picture. Between 0.5 per cent and 15 per cent of the pesticides that are applied to the crops end up in aquatic systems. Persistent pesticides, like DDT, linger in the sediments of rivers, lakes and oceans decades after they have been banned. Pesticide residues are now known to occur in most food we eat.³⁵ While the levels of their occurrence are small and usually within government safety standards, their potential synergistic effects are not known. While particular incidents may stand out in public memory because of sensational press coverage, far more ominous in the long term is the continual small dosage received each day by the majority of the population. Carcinogenic potential has long been acknowledged, and more recently the potential problems associated with hormone-mimicking pesticides has come to the public's attention.³⁶

From fertilizer application to 'dead zones'

There is another problem with industrial agriculture. It probably started in the early 19th century when Justus von Liebig first discovered that you could put inorganic chemicals on the ground to increase plant growth, as described earlier. The problem of soil fertility was thus, in principle, solved. But soil management proved to be far more difficult than had been expected. Once farmers started applying synthetic fertilizers they reduced or abandoned many of the old practices that ensured an ample supply of organic matter in the soil, such as cover crops, rotations with legumes and others. With time, the more synthetic fertilizer was applied, the less organic matter was left in the soils and the more synthetic fertilizers were needed. While not as well understood as the mechanisms of the 'pesticide treadmill', it is generally understood that provisioning the soil with large amounts of inorganic ions disrupts the normal nutrient cycling processes in the soil, thus making it even more necessary to apply fertilizers. While it does not seem to have been referred to this way before, it seems justifiable to refer to it as the 'fertilizer treadmill'.³⁷

As noted earlier, the process of nutrient cycling is complex. For the farmers this complexity is compounded by the variable needs of plants at different times. As a crop grows, its nutrient requirements change. So, for example, when a bean crop is at the point in its life cycle where it is filling its seeds, a large amount of nitrogen is needed. If that nitrogen is not available at that time, the seed-filling process will be slower, and may come to a halt if the local abundance of nitrogen is not sufficient. This is why frequently a side dressing (an extra amount) of nitrogen is added to a field at the time of seed filling. However, applying exactly the right amount of nitrogen to perfectly satisfy the needs of the crop, could very well be a week by week, or even a day by day, process if the supply is with nitrate or ammonium (the two ions that are directly taken up by the crop's



Figure 3.4 (a) Manzanar concentration camp, California, in the mid-1940s, where Japanese Americans were imprisoned during World War II; (b) recent photo of a broccoli farm in the Salinas Valley of California

Source: (a) Ansel Adams; (b) John Vandermeer

roots). Thus, it makes sense simply to apply an overabundance of either of these ions, such that there will always be as much as the crop needs, no matter what its growth phase might be.

Indeed, this was the general philosophical position of the soil fertility management establishment. Supply as much of the nutrient as is necessary, but be sure that the minimum amount is always there, which automatically leads to the application of more than is necessary. The problem is that nutrients that are not absorbed by the plants do not stay in the soil forever, they go somewhere else. Depending on the structure of the soil, the nutrient ions may be leached out of the system extremely rapidly, especially nitrate. The unabsorbed nutrient ions either go deeper into the soil or into the ground water, and out of the reach of plant roots, or into the waterways as part of the agricultural runoff.³⁸

Fertilizer runoff from farm fields in the Mississippi River basin have created a 5000 to 7000 square mile (13,000–18,000km²) 'dead zone' area of oxygen depletion (hypoxic zone) in the Gulf of Mexico.³⁹ These so-called 'dead zones' are now popping up at the mouths of many of the world's major rivers, at least those that catch the drain from farm fields engaged in the industrial model of agriculture. So far, 'dead zones' have been identified for more than 400 aquatic systems covering an area of more than 245,000 square kilometres and posing a significant threat to aquatic biodiversity (Figure 3.5).⁴⁰



Figure 3.5 *Global distribution of more than 400 'dead zones'*

Source: Diaz and Rosenberg (2008)

In conclusion, an unsustainable system

At a most general level, the extensive use of biocides and inorganic fertilizer may in the end prove to be self-defeating, since such use may be undermining the resource base on which agriculture is founded, especially on many tropical soils. The natural enemies that naturally control the populations of herbivorous insects are destroyed by pesticides, and the

herbivorous insects evolve resistance. The bacteria and fungal communities of the soil are thrown out of whack by the massive application of nitrates and phosphates, interfering with the natural process of nutrient cycling. And the destruction of other ecosystems and the potential livelihoods they support, from freshwater fisheries to the previously bountiful ocean resources, is monumental. More and more, this industrial agricultural system appears to be like an out-of-control adolescent for whom a concern for the future is at best a minor irritant. An additional ominous trend, and directly relevant to this book, is the loss of biodiversity from the expansion of the industrial agricultural system. Industrial agriculture, with its emphasis on large monocultures as opposed to the usually highly diverse traditional systems, on large-scale mechanization and irrigation, and on chemical pesticides and fertilizers, impacts both on planned and associated biodiversity. The consequences of this trend are yet to be fully appreciated, but analysts the world over are in agreement that the loss of biodiversity in general⁴¹ and specifically in agro-ecosystems,⁴² is somewhere between severe and catastrophic.

THE ALTERNATIVE MOVEMENT

Facing the evident problems generated by the industrial agricultural system, especially with its penetration into the Global South as the Green Revolution, not surprisingly, a vigorous alternative movement has emerged. We have written extensively about this movement elsewhere,⁴³ and here provide a summary as it relates to the specific topic of this text. First, we note that there is a long history associated with the alternative movement, beginning with practitioners who foresaw the future problems. Second, we summarize the more recent search for models that the movement seeks to emulate, either wholesale or in part.

A long tradition

While agriculture was rapidly being 'modernized' along the industrial pathway described above, millions of small-scale farmers all over the world were practising traditional forms of agriculture. These traditional practices serve as suggestive models for an alternative agriculture movement that started in the early part of the 20th century. Indeed it is not all that surprising that one of the first and most important moves toward the development of an alternative to industrial agriculture occurred in one of Britain's main colonies, India. According to the Council for Agricultural Science and Technology, Sir Albert Howard, Director of the Institute of Plant Industry in India early in the 20th century, was the first to describe the organic system as something distinct from the pathway that world agriculture seemed to be taking.⁴⁴ Howard noted, we think perceptively, that von Liebig's approach to the soil was strongly contrasted to that of

Darwin, as reflected in the latter's treatise on earthworms.⁴⁵ Whereas Liebig insisted on a reductionist approach, reducing the soil to nothing more than its chemical constituents, Darwin correctly saw the soil as a complex biological system. Perhaps Darwin was really the first advocate of an ecological approach to the study of soil.

Howard was a keen observer of local customs. In particular he observed the techniques applied by traditional Indian farmers in all aspects of their production. He was especially interested in the composting process commonly practised on traditional farms. From these observations he developed a system of composting (called Indore composting), which effectively remains the underlying idea behind modern composting.⁴⁶ He regarded Indian traditional farmers as his main instructors in agriculture, noting, for example: 'by 1910, I had learnt how to grow healthy crops, practically free from disease, without the slightest help from [...] all the [...] expensive paraphernalia of the modern experiment station.'⁴⁷ He also noted that traditional Chinese farmers were perhaps even more efficient than their Indian counterparts. His approach, which we can presume came from extensive observations of and conversations with Indian farmers, was focused on the health of the soil, arguing that a 'healthy' soil, by which he meant one that contained a well-balanced mixture of worms, fungi, bacteria and other micro-organisms, would produce healthy food; while a soil devoid of those healthy elements would not. Indeed, the connection between ecological health on the farm and the health-promoting qualities of the food produced there was a key element of the early organic movement, and, as we shall see, is emerging as a key element in the burgeoning alternative agriculture movement.

A variety of other tendencies began to emerge during the early 20th century in Europe, one of the most important of which was the work of Richard St Barber Baker. Serving the British Empire mainly in Africa, St Barber Baker, partly due to his upbringing as an evangelist's son, felt a religious tie with forested lands. After obtaining his Forestry degree from Cambridge in 1919, he was assigned to Kenya, where he found, unlike the 'healthy' farming practices of India observed by Howard, a scarred landscape, devastated by centuries of wheat farming introduced by the Romans and later by the introduction of goats by the Arabs.⁴⁸ He set out to reforest large sections of the country, a task for which he formed the 'Men of the Trees' movement (which remains active today as the International Tree Foundation). Much of interest is to be found in St Barber Baker's writings about forests, but for the purposes of this text, we note that he saw in the forests lessons that would become extremely important for the emerging organic agriculture movement: the natural cycling of nutrients occurred in natural forests, but not in many of the agricultural systems that displaced them. This is virtually identical to the ideology encompassed in the more modern 'natural systems' agriculture, as discussed below. In 1938, the first Men of the Trees summer school was held, and one of the featured speakers was Sir Albert Howard.

For real institutional representation we must wait until the end of World War II, when the modern industrial system really took off. In the 1940s, Lady Eve Balfour decided to convert her farm in England to a completely organic operation and began a series of long-term observations on the consequences. These became quite famous in organic agriculture circles and are known collectively as The Haughley Experiment, described in her book *The Living Soil*.⁴⁹ At about the same time, Swiss biologist Hans Müller, and German doctor Hans Peter Rusch founded the Organical-Biological Association in Switzerland in 1949. They soon expanded to Germany and Austria and were influential in promoting the idea that the health of the soil was something that needed to be maintained to ensure proper nutrient cycling in the agro-ecosystem. The Organical-Biological Association eventually gave rise to what have become the largest organic producer associations in the world: Bioland in Germany, VSBLO in Switzerland and Ernteverband in Austria.

In 1921, Jerome Irving Cohen, son of a Jewish immigrant family settled in New York, changed his name to Jerome Rodale. By the late 1930s he came under the influence of the organic farming movement, and in 1942 began publishing 'Organic Farming and Gardening'. Sir Albert Howard became an editor shortly after the magazine's first appearance. Even today, the magazine remains an important source of information on specific organic techniques. The Rodale Institute carries out cutting-edge research on organic production techniques, and remains an important source of research results for organic agriculture.

Throughout this short historical narrative one can see a continual critique, even if it is muted, of the Liebig approach. The soil cannot be seen as a passive sponge through which chemicals pass to plant roots. Modern soil science has come to accept this view on how the soil actually works, even if its origins in Liebigism compel it to continue its support of the chemical bias in the practice of agriculture. However, this is slowly changing, and the importance of what have been dubbed 'organic' methods are gradually making their way into the mainstream of soil science. The biological side of soils is now recognized as not only a legitimate component of soil science, but as essential. Indeed, in the UK, one of the premier promoters and certifiers of organic produce is the Soil Association.

Throughout the early development of an alternative movement, the problem of pests was dealt with in a consistent fashion. It was a common assumption that a 'healthy' farm would never have pests in the first place – the so-called health metaphor as described earlier. When pests arose, the proper way of dealing with them was first to eliminate them if possible, but, more importantly, to change production methods so the pest would not reappear the following year. Planned rotations in the developing alternative systems were as much associated with pest control as with soil fertility. As detailed above, the evolving industrial system changed all of that with its war metaphor favouring the application of biocides, but the alternative movement remained on course, thinking of pests as

a health problem – something that should ordinarily be handled by the complex ecological interactions that have always maintained ecosystems in a quasi-balance. Thus, adopting modes of biological and cultural management of potential pests was part and parcel of the alternative movement.

On the other hand, there is a certain institutional inertia that has more to do with politico-economic assumptions than with either chemistry or biology. The various soil and pest management schemes normally used by either indigenous or organic farmers usually consist of a set of rules, sometimes cultish (e.g. manure in cow horns buried for a year and later harvested as having recuperated their astral essence, a theoretical base for one of the preparations used in biodynamic agriculture)⁵⁰, yet sometimes surprisingly rational once properly understood (planting with the moon phase so as to coordinate crop phenology over a large area, thus satiating herbivorous pests). Since the dominant social form is the commodity production form of modern capitalism, traditional practices do not fit into the particular set of rules used in that system. Purchasing nitrate to satisfy the nitrogen demands of the crops means a product can be purchased by an entrepreneur and sold to a consumer, thus satisfying the underlying necessity of the system. If nitrate is supplied through biological nitrogen fixation, the entrepreneur is simply not needed. Converting the pest management system to one based on an integration of biological, physical and chemical forces operating in an autonomous fashion is likewise not expected to be popular under capitalism. A brute-force chemical approach is, almost always, more profitable according to capitalist accounting assumptions.

Finally, it should be noted that the history of the emerging 'formal' organic agriculture movement described above is Euro-Anglocentric mainly because the formal challenge to industrial agriculture emerged from those places where industrial agriculture was prevalent: Europe and the US. However, many of the ideas that were formalized in books and journal articles came from a myriad of traditional systems practised by indigenous and small-scale farmers all over the world. Indeed, as mentioned earlier, the origins of the movement can be traced back to Indian farmers practising traditional agriculture. In a sense, these ideas were the germ of what eventually became the science of agro-ecology, which combined general scientific knowledge about the ecology of agro-ecosystems with specific local and indigenous knowledge about particular agricultural systems.⁵¹

A wealth of models

In searching for a general plan for the transformation of agriculture from the industrial system to an ecologically sound and sustainable one, we most naturally look to models, both for how the new agriculture will look and for how to transform the present system. Traditional or indigenous

systems present us with one model, since by definition they were not subject to the same forces that produced the modern industrial system. Extant organic farms, isolated amidst the ocean of industrial agriculture, provide another. And a third model emerges from the idea that the design of agro-ecosystems should be based on the ecological dynamics of local natural ecosystems: 'natural systems' agriculture. All three of these models are discussed below. But before proceeding to that discussion, it is imperative to note that in all three of these models we are presented with systems in which some of the key social variables have been cancelled out of the equation. Traditional systems, by their very nature, do not exist in the context of industrial agriculture, but rather in semi-isolated pockets where the industrial capitalist system has not yet fully penetrated. Extant organic or ecological farms are mainly run by people whose attitudes have already been transformed, and who are largely unconcerned with promoting a global transformation, but are more interested in the survival and prosperity of their individual farms. And 'natural systems' agriculture is based on the local natural habitats before they were modified by the activities of humans. While it is clear that much is to be learned from these three models, we expect that most of this knowledge will be of a technical sort, leaving us still to ponder the vexing social and political questions about the transformation.

Traditional agro-ecosystems

Many authors have promoted the idea that traditional or indigenous forms of agriculture, since they have not undergone the alterations of the industrial system, offer models wherein particular practices can be modified to fit into the transformation. Most claim that traditional systems are likely to contain rules of operation that have survived the test of time and may represent signposts along the road to an ecological agriculture. The general attitude is summed up by Miguel Altieri, an agro-ecologist at the University of California, Berkeley, US:

... ecological principles extractable from the study of traditional agro-ecosystems can be used to design new, improved, sustainable agro-ecosystems. [...] traditional farming systems have emerged over centuries of cultural and biological evolution and represent accumulated experiences of interaction with the environment by farmers without access to external inputs, capital, or scientific knowledge. Such experience has guided farmers in many areas to develop sustainable agro-ecosystems...⁵²

While this is certainly a good working assumption when studying traditional agro-ecosystems, it needs to be tempered with some scepticism. Although many traditional systems, when kept from external influences that alter them, have persisted for hundreds and perhaps thousands of years being productive and with little negative environmental impacts, others have proven to be less sustainable. Examples exist from the salinization

of croplands by the Hohokam in southwestern North America⁵³ and Mesopotamia,⁵⁴ to the massive soil erosion that destroyed Greek ecology during the classical Greek civilization.⁵⁵

Traditional systems share a surprising number of tendencies at a very general level.⁵⁶ They tend to have a very highly planned and associated biodiversity, and to employ that biodiversity to utilize all available habitats in the agro-ecosystem. Nutrient cycling tends to be closed, with kitchen wastes and animal manures as a key part of the cycle. The management of pests tends to be incorporated into the overall management of the system. Inputs tend to be mainly derived from recycling on the farm, with very few inputs from outside the farming system.

Whether such tendencies can or should be applied to the development of modern systems will obviously be conditional and site-specific. Some are relatively obvious or are well sustained by scientific evidence, and are already part of the principles of sustainable agriculture (e.g. the entire philosophy of 'Low Input Sustainable Agriculture' is to recycle so as to reduce external inputs to as low a level as possible). Others, especially those that require more labour, evoke ridicule when suggested to farmers in the developed world (e.g. try suggesting to a European farmer that he or she should use animal traction). But one thing is clear: specific technologies used by specific cultures represent, in a sense, the raw material of ecological development. It is not that we should try to convert all the mountains of southern Mexico to intercrops of beans and maize (the system frequently employed by traditional farmers there), but rather that we should view this method of maize production (intercropping) as a principle that could be adapted for use elsewhere.

We suspect that the general principles outlined above have already been indelibly etched in the minds of all those who seek to transform agriculture. The real value of traditional systems as models is in the specific and particular techniques they use. But, since traditional farming is not static, and farmers are always experimenting and incorporating new techniques into their 'traditional' farming systems, the agro-ecologist, in collaboration with these traditional farmers, is constantly studying, experimenting and incorporating these new techniques. The value of traditional knowledge and wisdom has recently emerged as an important component of the critique of the conventional, industrial agricultural system. Indeed, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) highlights traditional and local knowledge as a key component of the process of transformation of the current agricultural system. Their report notes: 'Traditional and local knowledge constitutes an extensive realm of accumulated practical knowledge and knowledge-generating capacity that is needed if sustainability and development goals are to be reached.'⁵⁷ Farmer-researcher participatory approaches have been found to augment and sometimes even replace conventional technology-generating approaches.⁵⁸ In this regard, examples abound where traditional and indigenous farmers



Figure 3.6 *Indigenous youth of the Andean region of Peru participating in a programme oriented at the valorization of Andean culture and agriculture, organized by the Proyecto Andino de Tecnologías Campesinas (PRATEC)*

Source: Julio Valladolid

and researchers work side by side to develop and implement sustainable agricultural technologies (Figure 3.6).

The experience of Cuba in its transition to a more ecologically sound form of agriculture is also instructive.⁵⁹ In the early 1990s, with the collapse of the Soviet Union, Cuba lost its major trading partner, and with it, its main supplier of cheap fertilizers, pesticides, petroleum and animal feed. This proved to be a disaster for Cuban agriculture, which was among the most intensive of Latin America. Within a year, yields of all crops collapsed and the Cuban population went hungry for the first time since the triumph of the Cuban Revolution 30 years earlier. It became evident to most Cubans that their intensive agriculture, previously a source of pride, had made them vulnerable to external forces beyond their control. For the agricultural research system in Cuba it became imperative to search for alternatives. A major impediment to the development of an alternative model was the lack of locally tuned knowledge about particular ecological circumstances, a consequence of 30 years of almost religious commitment to the industrial model. At this point agricultural researchers sought the help of the few traditional farmers that were left in the country and began a process of learning and integration of traditional and scientific knowledge. To a great extent, it was the intimate relationship between local or traditional knowledge and systematic scientific knowledge that laid the foundations of the new alternative agricultural system in Cuba.

As ecologist Richard Levins has noted, academic knowledge is general but shallow, while local knowledge is specific and deep.⁶⁰ Local knowledge is frequently 'flawed' in terms of modern ecological understanding, yet it is set in a world view that provides it with context. The fact that a local farmer in Nicaragua 'knows' that grasses 'burn' the corn, is not ultimately different from the scientific ecologist's 'knowledge' that the corn 'dries out' because of 'competition' from grasses. Whether we say 'burn' or 'competition' really only identifies the discourse under which the actual observation of the corn's performance in association with grass is communicated from one person to another. The fact that the farmer knows the details of what happens to the corn when grasses grow around it is key to developing local alternatives that work. The fact that the ecologist uses the word 'competition' to describe the phenomenon brings the rest of the experience of the world, to the extent that it is catalogued, as possible knowledge for the planning process. The farmer knows what happens in his or her field. The ecologist can generalize that knowledge, compare it with what happens in other fields, effectively expanding the potential knowledge base.

The deep and local knowledge of the farmer, especially the traditional farmer, is essential to the ultimate development of the alternative model. The ecologist may help generalize and contextualize that knowledge to actually make it richer, but the local knowledge is imperative due to the unpredictability and locality-specific nature of many ecological processes.

However, much traditional knowledge has been lost during the past 50 years due to the hegemony of the industrial model. We are faced with the problem that today's world is filled with urban workers, while what we need are rural ecologists. While this problem is not as universally recognized as the lack of appropriate technology, it may turn out to be a more important one.

We are thus faced with a major contradiction in the move to ecologically based agriculture. On the one hand, we do not have a complete catalogue of techniques that are tried and proven to work under all circumstances – the technical side of the contradiction. On the other hand, the destruction of rural society has taken with it the knowledge base and labour force that will be needed for the transformation – the social side of the contradiction. We confront the task of building a new system based on incomplete technical knowledge and with a society designed to function only under the current system. The truth is that we do not know, technically, how to control, for example, the whitefly in vegetable production in Central America. Yet even if we did have a technical solution, it is not clear that the local farmers or farm workers would be available and/or willing to undertake that procedure. As we strive to transform the current system, this is a principal contradiction that must be resolved. Local and traditional knowledge and wisdom may aid in resolving it.

Practising organic and agro-ecological farms

Extant organic or agro-ecological farms probably offer the best model for the way individual farms will look after the transformation. There has already been an explosive growth of this form of agriculture in many parts of the world. Although there are acknowledged problems with further expansion of this sector, it is worth noting that earlier warnings that the growth would soon halt were clearly premature.⁶¹ Indeed, the area devoted to certified organic agriculture continues to grow in all parts of the world. Today, almost 31 million hectares are in organic production worldwide (Figure 3.7).⁶²

To some extent, organic agriculture is largely based on what not to do, and arises as a counterpoint to industrial agriculture (but see also Lampkin's argument about what organic agriculture actually is, rather than what it is not).⁶³ Management of soil fertility with natural as opposed to chemical fertilizers; management of potential pests through natural as opposed to chemical methods; and increased planned and associated biodiversity, are the three main principles. Reversing the tide of chemical usage requires very different management skills than contemporary farmers generally have (especially when local and traditional knowledge is long gone), including crop rotations and careful management of soil nutrients. In Europe organic farms tend to be mixed farms, with animals providing what is effectively an acceleration of decomposition so that nutrients can be recycled more quickly. Feedstock produced in one field can be recycled through a cow and provide nutrients to another field through the cow manure. In principle, it is precisely the philosophy that was the basis of the rotational systems of Europe at the dawn of modernity.

Much of the benefit of contemporary organic, ecological farms is in the favourable position of organic products in the marketplace. On the one hand, we can probably expect an increase in demand for organic products as consumers become more educated about environmental and health issues related to industrial agriculture; but on the other hand, further expansion of organic production will inevitably lead to increased supply and a gradual erosion of the favourable market position. This strongly suggests that further refinements in organic methods, which will require serious ecological research, will be critical to the expansion of the organic sector in the future.

There is a point of view that tends to counteract political support for organic agriculture, namely that organic agriculture generally produces lower yields than conventional agriculture, and thus could never 'feed the world'. This point of view is wrong on two counts. First, in a careful review of the literature, Badgley and colleagues found that, contrary to the conventional wisdom, organic agriculture *could* potentially produce enough calories to feed the world.⁶⁴ By examining almost 300 studies from all over the world that compared yields in organic or agro-ecological farms with conventional farms we found that, on average, organic farms produce as much, if not more, than conventional farms. Of course, there

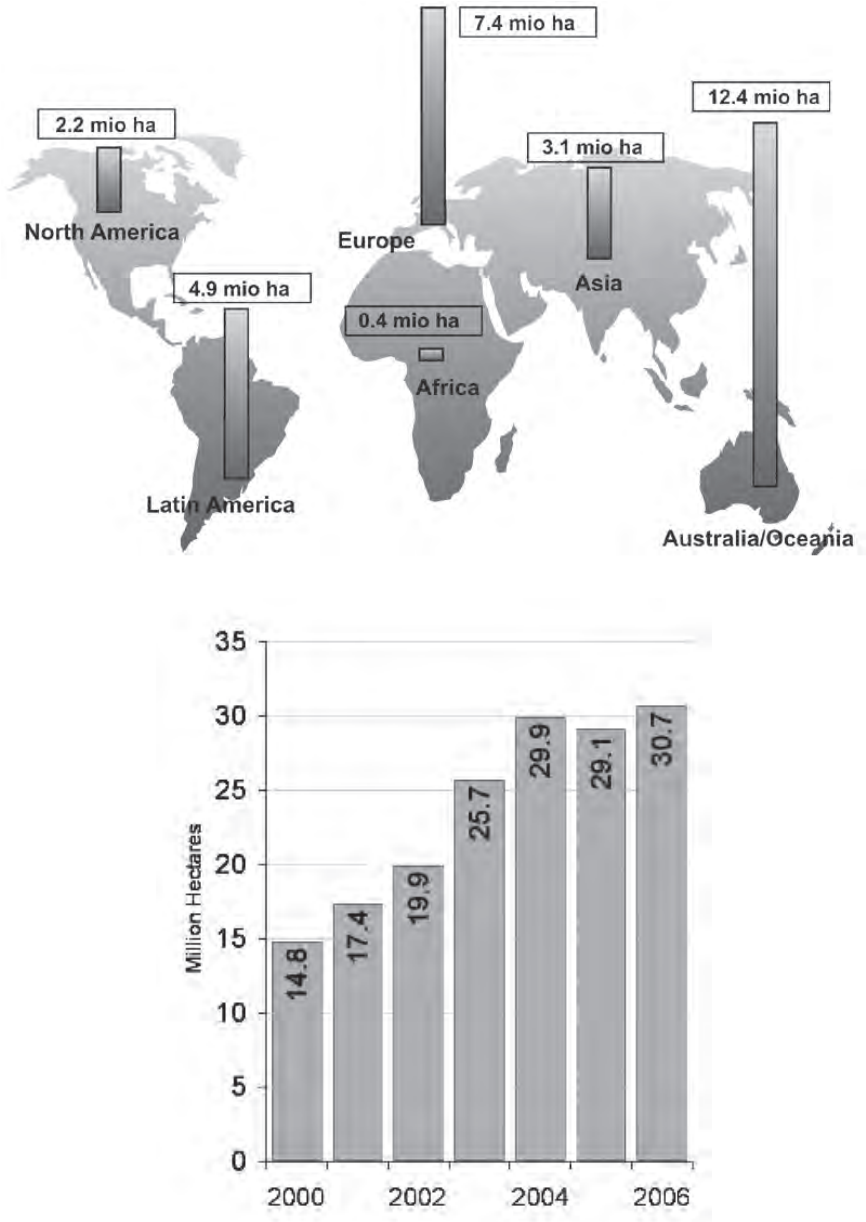


Figure 3.7 (a) Distribution of global organic land by continent, in 2008
(b) Growth of global organic land from 2000 to 2006

Note: These figures do not include wild harvest areas. In 2005, there was a slight decline in the area under organic production due to some grass areas in Chile, China and Australia being taken out of organics.

Source: FiBL Survey in Willer et al (2008)

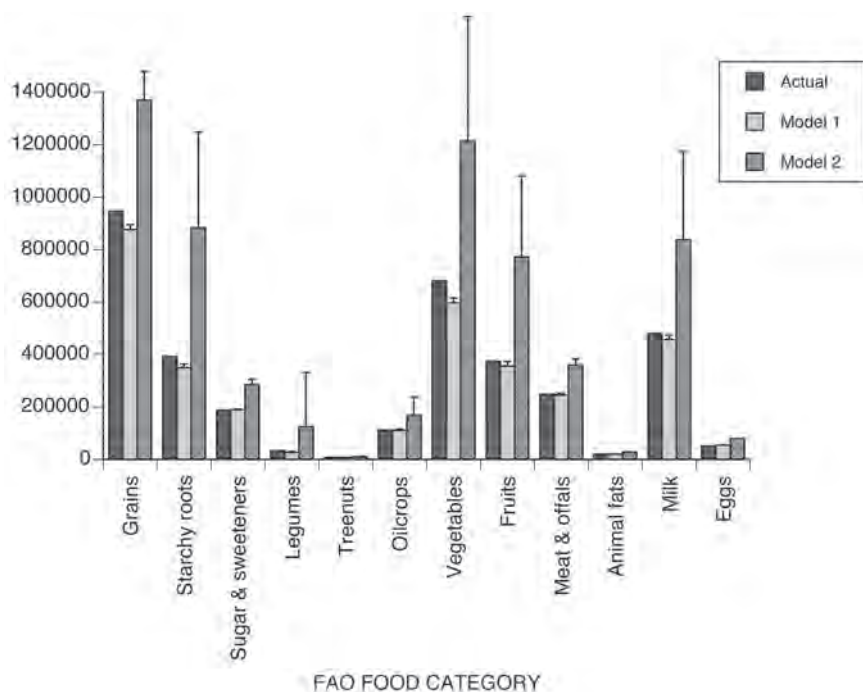


Figure 3.8 *Two estimates of global organic food production in comparison with actual food production in 2001*

Note: Model 1 uses organic/conventional yield ratios from developed countries and applies them to the entire world. Model 2 applies organic/conventional yield ratios from developed countries to food production in developed countries, and yield ratios from developing countries to food production in developing countries.

Source: Badgley et al (2007)

is some variability depending on site, crop and the actual management of the farms, but overall, organic and conventional farms have similar yields (Figure 3.8). One unexpected result of our study was that the yield ratios between organic and conventional farms were much higher for developing countries than for developed countries. In retrospect, this should not have been surprising since in developing countries the ‘conventional’ farms are far from efficient. For example, many conventional farmers apply fertilizers when they can get them, not when the crops need them the most. Our results simply say that a well-managed agro-ecological farm can be much more productive than a badly managed conventional farm. Proponents of industrial agriculture would argue that yields in developing countries could be increased dramatically with more chemical intensification. And they are right. However, our study suggests that farmers in developing countries can also increase yields dramatically with agro-ecological and organic techniques, for less money, using local materials, and without the

negative environmental and health impacts of industrial agriculture (and if their crops are oriented toward the market, with the added benefit of a premium price). Again, our results are hardly surprising. Looking at the problem as one of basic biology, a growing crop plant does not care about whether its nitrogen comes from compost or synthetic ammonium, or whether its natural enemies are killed by a parasitic wasp or a synthetic biocide. It will simply grow faster and yield more if it has sufficient nitrogen (and other nutrients) and is protected from its natural enemies. A crop plant has no politics. So, from basic biology we really do expect equal yields from organic versus conventional farming, and the popular notion that organic is less efficient comes from a socio-economic argument and a programme of political propaganda.

The second reason that it is wrong to think that organic agriculture could never 'feed the world' is the following: there is an assumption that conventional agriculture will be allowed to continue its practice of externalization, while organic agriculture will receive no substantial support from governments. This is a frequently hidden ideological assumption that may be true, but, depending on political arrangements, may very well change.⁶⁵ As in many other industries, those with economic interests behind industrial agriculture are powerful and influential, promoting their own interests through official and extra-official channels. The environmental consequences – from the creation of secondary pests to the elimination of biodiversity, to the creation of 'dead zones', to soil erosion and loss of soil fertility, to secondary environmental contamination, etc. – have been allowed to be written off as externalities: a cost that is absorbed by society. While no study has tried to quantify all of the costs actually associated with the industrial system of agriculture, some have quantified particular aspects of it. For example, Pimentel and colleagues estimated that pesticide use costs US taxpayers approximately 8 billion US dollars every year, most of which is located in the hidden subsidies in the externalities.⁶⁶ If popular pressure builds for a more equitable accounting, conventional agriculture may come under more careful scrutiny and be forced to pay for some of the real costs of production that are currently absorbed by society. In US superfund sites, for example, many of which result from dumping the by-products of pesticide production, clean-up costs are so extreme as to render the original production process a net drain on the overall economy. Only through the indirect subsidy provided by a government subjected to intense industry lobbying are these products able to compete. If sufficient political pressure were applied, such subsidies could become a thing of the past, and the conventional agricultural system would probably collapse.

On the other hand, if awareness of the importance of conserving the environmental base of agriculture grows, political pressure could build for governmental support for organic and agro-ecological conversion and production. If and when, and how much, are impossible to predict, but the possibility that such a change could occur cannot be discounted.

Finally, when discussing organic agriculture as a model, a flag of caution should be raised. Our discussion has emphasized the benefits of organic production for the environment in general, and for the issue of the sustainability of agriculture itself. However, for the purposes of our basic argument, there is something more transcendent about organic production, and that is its extent: the way in which it articulates with neighbouring managed and unmanaged parcels of land. The growing tendency for organic production to morph into large monocultural agribusinesses, due to the increasing demand for organic food, may sometimes be antithetical to the needs of a high-quality matrix. In a capitalist economy, where growth is an imperative of any business, organic agriculture is bound to follow this imperative. Ironically, the success of organic agriculture could become the seed of its own destruction. This is already happening to a great extent in the processing and retailing sector, both of which have seen significant acquisition and merger activity over the last few years. How much of this consolidation is also happening in the organic farming sector is hard to know, but the trend seems to be in the same direction. More frequently, large industrial farms are turned into large organic farms to take advantage of higher prices. The organic mega-farms are characterized by an input substitution model rather than an agro-ecological model. This means that instead of diversifying the system and harnessing the biological processes generated from within the farm to maintain fertility and regulate pests, the farmer specializes in one or a few crops, applies organic fertilizers and pesticides and keeps pretty much the same type of management as the conventional farms.⁶⁷ If, as we suspect, the agro-ecological model is the one that will most likely lead to landscapes that are biodiversity-friendly, this tendency of growth and consolidation of the organic sector is not positive. Its overall effects on associated biodiversity are probably negative and, more importantly, the social and economic impacts it generates are as devastating for rural communities as those of conventional agriculture.

NATURAL SYSTEMS AGRICULTURE

With a focus specifically on biodiversity conservation, it seems a no-brainer to suggest that an agro-ecosystem should reflect the natural vegetation in the region in which it is practised.⁶⁸ Perhaps the most vocal proponent of this idea is Wes Jackson, who reasons that agriculture in grassland areas (which is where the most important cereal production in the world occurs) has gone wrong because the natural ecosystem in such an environment is a perennial polyculture, unlike the artificial annual monoculture that has replaced it.⁶⁹ The fact that we produce annual monocultures in those areas is simply due to our inability to domesticate perennial grasses. Jackson's vision is to domesticate wild perennials and hybridize crops with perennials' relatives (Figure 3.9). The particulars of Jackson's vision

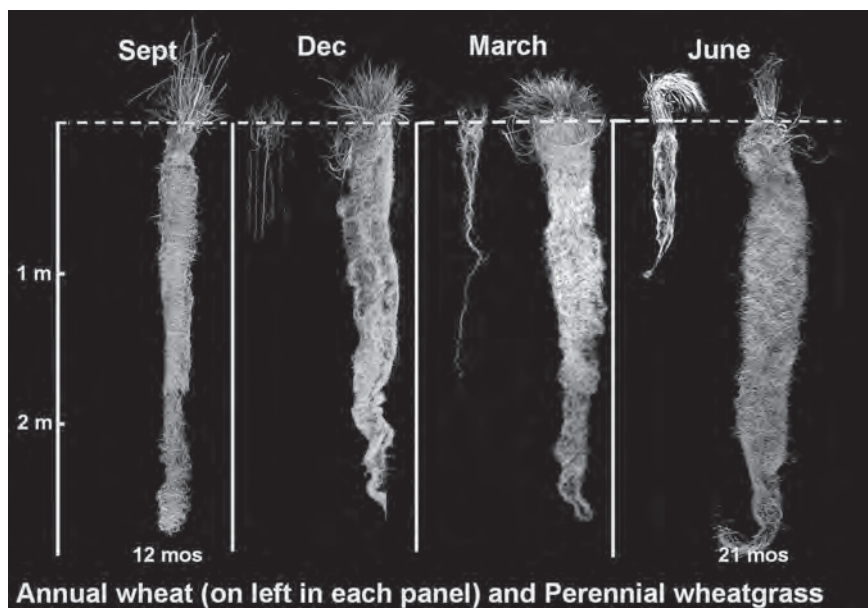


Figure 3.9 *Root system of an annual and a perennial wheat*

Note: As can be seen, the root biomass of the perennial wheat is much higher than that of the annual wheat. The Land Institute has been working on developing perennial grains that can be used for food, and at the same time maintain the integrity of the soil by mimicking the natural prairies of the central plains of the US.

Source: Land Institute, Salinas, Kansas

are somewhat more specialized than the others mentioned in this section, but his logic warrants considerable attention, in particular because 80 per cent of global agricultural land is devoted to annual cereal grains, legumes and oil seed crops.

It must be acknowledged that, in one way or another, the idea of 'natural systems' agriculture has been part and parcel of the organic movement since its popularization in the 19th century. For example, when Ehrenfried Pfeiffer examined the problems of Florida's citrus groves, he looked to the nearby native forests for insights into what was wrong with the agroecosystem, finding, not surprisingly, that monocultural production would probably lead to diseases. He suggested planting native trees among the oranges so as to protect against such problems: a clear example of learning from the local natural system. In fact, according to Conford:

This story fits well into the organic mythology in the morals that it offers: respect for the natural order as revealed particularly by the wilderness

brings economic benefit to those who are not fixated on short-term gains; true science goes out from the laboratory and studies the ecological context, observing rather than trying to dominate; variety is more productive than monoculture; industrial products bring disease and waste.⁷⁰

It is worth noting that some other already extant agro-ecosystems correspond quite well to Jackson's vision of 'natural systems' agriculture. As noted by various authors, traditional tropical agro-ecosystems tend to be complex multi-storeyed polycultures that have certain features that resemble the natural forest that they replaced, including the so-called *cabruca* cacao of Brazil (see Chapter 5), the jungle rubber of Southeast Asia and almost all traditional home gardens located in the humid tropics.⁷¹ Most impressive are the thousands of hectares devoted to coffee cultivation (see Chapter 5). Traditional coffee production ranges from 'rustic' to polycultures of overstorey trees. In rustic production the original forest remains, except that the understorey has been replaced by coffee bushes. The entire ecosystem looks very much like a natural forest. Indeed, aerial photos invariably fail to distinguish rustic plantations from natural forests.

BIODIVERSITY AS IT RELATES TO AGRO-ECOLOGY

From the previous sections, two of our positions should be evident. First, that the industrial agricultural system was the natural child of an emerging capitalist economic system and as such contributed to maintaining the structures of capitalism. And second, that there are many proven alternatives that are beginning to challenge the hegemony of the industrial agriculture model. Yet the specific relationship of the industrial model to biodiversity remains implicit: deducible, we feel, from a knowledge of both recent empirical work in agro-ecosystems themselves and from recent theory in the science of ecology that emphasizes the importance of migration in metapopulation and metacommunity structure. In this section we summarize first the issue of biodiversity in agro-ecosystems itself, and second, the important question of the agro-ecosystem as part of a high-quality matrix.

Biodiversity in agro-ecosystems

Contemporary literature increasingly recognizes that agro-ecosystems can be rich repositories of biodiversity.⁷² Nevertheless, a common approach taken by those concerned with biodiversity conservation, has been to buy land for conservation, introduce fences and guards with guns, mainly metaphorical but sometimes real, around those areas and hope for the best.⁷³ This so-called 'fortress approach'⁷⁴ not only ignores

the importance of those areas for the livelihood of rural people, but most importantly for biodiversity conservation, it ignores the importance of the matrix in maintaining biological diversity. The extreme conservationist position tacitly assumes that when the original habitat (whatever that is) is converted to a managed system (e.g. an agro-ecosystem) the biodiversity is simply lost. Some would compromise, and admit that there is some biodiversity in managed ecosystems, but will qualify the term 'biodiversity' with adjectives such as 'trash', 'opportunistic' or 'non-forest species'. The literature now abounds with falsifications of that point of view, two examples of which are the coffee and cacao systems that we discuss in Chapter 5. Agro-ecosystems can be rich repositories of biodiversity, depending on how they are organized. A typical grape orchard in the Central Valley of California is reminiscent of the opening lines of *Silent Spring*, but a traditional coffee farm in the mountains of Chiapas contains as many ant species as an adjacent forest, and the mornings are filled with delightful birdsong. If you convert that traditional system to a pesticide-drenched coffee monoculture, many ant species will disappear and the mornings will be silent.

Agro-ecosystems as migration routes

From the point of view of ecological theory, there is every reason to expect that local populations go extinct on a very regular basis, only to be reinvigorated by migrations from other localities. This pattern is likely to occur even in habitats totally undisturbed by *Homo sapiens*. However, the principle becomes even more important when dealing with fragmented habitats. All of this was presented in detail in Chapter 2. Recall that the fundamental equation of metapopulation biology is $p = 1 - e/m$, where p is the fraction of potential habitats actually occupied by a species, e is the extinction rate and m is the migration rate. Obviously, as long as m is larger than e , the ratio e/m will be less than 1 and the fraction of potential habitats occupied will be greater than 0. But if m begins to decline (or e increases), a larger problem arises: as m approaches e , according to the standard equation, the population becomes regionally extinct (p approaches 0). While local extinctions cannot be avoided, which is to say there is little we can do about e , regional and even global extinctions can indeed be averted by concentrating on m , the migration coefficient; which is to say, by constructing agro-ecosystems that are conducive to inter-fragment migration.

In summary, we have argued in this chapter that the post-World War II period saw the evolution of a worldwide system of agriculture that is historically unique – based on monocultures and the use of agrochemical inputs. This industrial system is young and, despite much trumpeting, its long-term survival or sustainability has been called into question.⁷⁵ In addition to the poisoning of the environment and the threat to human health, this system has been devastating for biodiversity. Understandably,

a great many people have come to the conclusion that the industrial agricultural system is too damaging to both the natural and social environment, and needs to be transformed dramatically. Parallel with this analysis is the argument of this book – the industrial agricultural system must be transformed if we are to avoid massive extinctions of species in tropical areas. In the rest of this book we discuss the broad social context in which this transformation must occur (Chapter 4), present examples that illustrate the interconnection between the ecological theory, agro-ecology and the social movements (Chapter 5), and finally weave this all together into a new conservation paradigm (Chapter 6).

NOTES

- 1 This type of agriculture is also called *Swidden* agriculture.
- 2 Boserup (2005).
- 3 Tinker et al (1996).
- 4 Chacon and Gliessman (1982).
- 5 The IAASTD (2009b) is an intergovernmental initiative sponsored by the World Bank, various UN agencies and various participating countries. It had more than 400 expert authors and was approved in Plenary by delegations from 54 countries. The US, Canada and Australia refused to sign due, largely, to the document's conclusions about biotechnology and agricultural trade.
- 6 Polanyi (2001).
- 7 The interest in bio-fuel has led to a rapid increase in oil palm plantations throughout much of the tropics. However, tropical fruits, such as pineapples and bananas, continue to devastate many areas in the tropics.
- 8 The Law of the Minimum was a principle first developed by German botanist Carl Sprenger in 1828, but further developed and popularized by Justus von Liebig (Brock, 2002).
- 9 Goodman et al (1987).
- 10 Smil (2004).
- 11 Nassauer et al (2007); UNEP (2007); Diaz and Rosenberg (2008).
- 12 Himmelberg (2001).
- 13 De Janvry (1981).
- 14 Peet (1969).
- 15 Russell (2001).
- 16 World Health Organization (1979).
- 17 Wright (2005).
- 18 IAASTD (2009b).
- 19 Wright (2005).
- 20 Lewontin (1982).
- 21 Recent technological and institutional changes in some sectors have facilitated the takeover of 'farming' by large corporations. This is most evident in factory farming where the 'farmer' contracts with a large corporation that stipulates all conditions of production (Lewontin, 1998).
- 22 Lewontin and Berlan (1986).
- 23 Vorley (2003).
- 24 Reardon et al (2003).

- 25 National Research Council (1989); Pimentel et al (1995); Pimentel (1996); Matson et al (1997); Tilman (1999); Heller and Keoleian (2003).
- 26 Buttel (1990).
- 27 Domsch (1984); Curry (1994); Gunapala and Scow (1998); Neher (1999); Finegan and Nasi (2004).
- 28 Swift et al (1996); Black and Okwakol (1997); Giller et al (1997); Matson et al (1997); Altieri (1999); Tscharntke et al (2005).
- 29 Swift et al (1995).
- 30 Carson (1962).
- 31 Carson's book focused on persistent pesticides (those that last in the environment for decades). Different problems emerged with non-persistent pesticides because they tend to be more toxic (Perfecto, 1992).
- 32 Lee (1962).
- 33 Colborn et al (1997).
- 34 Van den Bosch (1978).
- 35 Pimentel and Lehman (1993).
- 36 Steingraber (1998).
- 37 Drinkwater and Snapp (2007).
- 38 This problem is substantially different in organic production, since the source of all nutrients is from decomposition, effectively a slow-release nutrient-supplying system. However, the technical problem is similar in that the challenge is to provide exactly the right amount of nutrients needed at any point in time, and to avoid excessive nutrients from leaking out of the system.
- 39 Rebalais et al (2002); Nassauer et al (2007).
- 40 Diaz and Rosenberg (2008).
- 41 Wilson (1986).
- 42 Black and Okwakol (1997); Giller et al (1997); Matson et al (1997); Donald (2001); Kremen et al (2002); Benton et al (2003); Tscharntke et al (2005); Perfecto and Vandermeer (2008a).
- 43 Vandermeer (in press).
- 44 Conford (2001); Heckman (2006).
- 45 Darwin (1881).
- 46 Howard (1940); Niggli and Lockeretz (1996).
- 47 Conford (2001).
- 48 St Barber Baker (1985).
- 49 Balfour (1950).
- 50 The biodynamic agriculture movement was initiated by a series of lectures given by Rudolph Steiner in the 1920s. It is frequently described as 'organic plus' and involves a host of semi-mystical procedures based on concepts such as 'astral power' and 'the inherent energy of the earth'. While still practised extensively in Europe, it is a movement that is not well-substantiated using standard Western scientific standards.
- 51 Altieri (1987, 1990).
- 52 Altieri (1990).
- 53 Fish (2000).
- 54 Jacobsen and Adams (1958).
- 55 Runnels (1995).
- 56 Altieri (1990).
- 57 IAASTD (2009b).
- 58 Fals-Borda (1987); Nelson (1994).

- 59 Funes et al (2002); Wright (2008).
- 60 Levins (1990).
- 61 e.g. Landell-Mills (1992).
- 62 Willer et al (2008).
- 63 Lampkin (2003).
- 64 Badgley et al (2007).
- 65 e.g. van Mansvelt and Mulder (1993).
- 66 Pimentel et al (1992).
- 67 Roberts (2008).
- 68 e.g. Soule and Piper (1991); Ewel (1999).
- 69 Jackson (1980, 1985, 1996).
- 70 Conford (2001).
- 71 Altieri (1990); Ewel (1999); Gliessman (2006).
- 72 Harvey et al (2008); Perfecto and Vandermeer (2008a).
- 73 Oates (1999); Terborgh (2004).
- 74 Brockington (2001).
- 75 IAASTD (2009b).

The Broad Social Context for Understanding Biodiversity, Conservation and Agriculture

THE IMPORTANCE OF THE DEEP HISTORICAL CONTEXT

Conservationists are often very impatient people. The race to save species and habitats imposes a sense of urgency because of how rapidly biodiversity is disappearing and how quickly habitats are being made unfit to support species. But if a key element in the new conservation paradigm is the type of agro-ecosystem generated in the matrix, then the socio-political forces operative in that matrix are key to the entire conservation programme since they form the foundation upon which the agro-ecosystem evolves. For example, a rural development policy based on the industrial model is likely to reproduce what we today see dominating large parts of the San Joaquin Valley of California or of northern Iowa – a landscape that allows little room or opportunity for the survival of anything but the crops being produced. Much of the current agricultural development for soybeans and sugar cane (grown largely for ethanol fuel production) in Brazil follows this rigid industrial model that tends to obliterate biodiversity and provides a very low-quality matrix for movement and reproduction of organisms (Figure 4.1). As an alternative example, the exigencies created by the fall of the Soviet Union generated socio-political and economic forces in Cuba that forced a totally different model resulting in a rural environment on its way to the sort of high-quality matrix we advocate.¹ Today there are a large number of rural social movements challenging the industrial agrarian system that we identify as beginning with the spread and dominance of the European powers. While it is understandable that conservationists are impatient to get on with the task, they cannot afford to ignore either the general conditions established in the process by which European nations and their heirs (e.g. the US) transformed the surface of a large share of the planet, or the specific conflicts and problems generated.

There has been a disturbing tendency for conservationists to see landscapes in the tropics, as elsewhere, as representing in some sense an original condition. For example, they have seen tribal peoples in Africa in



Figure 4.1 *Soybean fields surrounding a forest fragment in Brazil*

Source: Michael Grunwald, *Time Magazine*, 27 March 2008

a certain relationship to the landscape, plants and animals, and take what they see as the given condition of the place over an extended period. What they miss in this is that very few landscapes in Africa or anywhere else have escaped processes of major change over the last 500 years, influenced by many factors internal and external, but almost always transformed strongly by the history of European discovery and dominance.² In the case of Africa, conservationists eager to throw up a boundary around wildlife have often given little attention to the rather recent dispossession of African peoples by European settlers and by mining, timber and agricultural corporations.³ Thus, too little thought was given to the problem of both human and other species' survival within and around reserves on land that remained available after the richest land for both people and other animals had already been seized for European agriculture.

But the problem is much deeper still. The massive taking of slaves out of Africa radically changed the relationship of various tribes and nations of Africa to one another, as some were largely the victims of slave raiding, and others engaged in slave raiding to capture slaves to sell to the trade that would take them across the Atlantic. Other critical changes were

brought about by the imposition of taxes that had to be paid in currency, the creation of artificial boundaries that disrupted traditional methods of livelihood (e.g. pastoralism, hunting, seed gathering, agriculture and trade), the creation of armies equipped with modern weapons, and indeed, the entire shock brought by foreign occupiers to a varied landscape and highly diverse peoples. All of these factors have played a significant role in the diverse human and environmental problems that continue to emerge: for example, the expansion of the Sahara desert southward and the periodic famines and armed conflicts in the region. Most of these factors have had major implications for the plants and animals throughout Africa, as well as for the diverse human communities.⁴

In the African context, the effort to preserve large mammals in extensive reserves came to Africa as an activity that was as strange and disruptive in many ways as were the very European influences that had brought those mammals under threat. A large literature now exists based on the relatively recent recognition of these factors and the enormous complications and difficulties set in motion by conservation activities in Africa. This literature attempts to identify alternative methods and policies that might create a new and more satisfying balance between human cultures and the legitimate desire to protect species. There is a relatively wide-spread recognition that failures to take into account the human historical and cultural context have undermined both human welfare and prospects for species survival in a distressingly large number of cases.⁵

The dilemmas of African wildlife conservation have become relatively widely known both because of the extremely high interest in the survival of African mammals and the severity of the problems associated with and often created by the attempt to protect them. It must also be admitted that Americans and Europeans have taken a larger interest than they might have in these problems because of, for better and worse, their tendency to see Africans, as well as African wildlife, as exotic and therefore interesting. The problem, however, is global, though in many cases less subject to transformation into handsome and captivating films. Nearly everywhere, the problem of conservation must deal with a long history of the interaction between local peoples, their landscapes, and the project of European political, economic and cultural dominance.⁶

European colonialism

Sorting out the effects of European colonialism and domination over trade and economies in terms of the implications for natural communities is no easy task. First, we must recognize that by 1492 human beings were transforming the landscapes and biota of the planet in an enormous variety of ways. The planet was not a clean slate upon which Europe wrote the world's destiny.⁷ China and India were civilizations that were in many, if not most, respects more 'advanced' in industrial enterprise, technology and governance than Europe. Intense and highly productive

agriculture covered large parts of Asia, especially where rice cultivation had been developed, transforming the physical landscape with drainage and irrigation works, terraces and paddy construction, as well as creating major shifts in plant and animal populations. Rulers, including Chinese emperors and Indian Moguls, had already responded in some areas by establishing reserves and rules regarding wildlife, forests and waterways, meant to maintain what we would now call a healthy and sustainable environment, or at least rich royal hunting grounds.⁸ In Mesoamerica, relatively dense populations maintained themselves by a combination of extensive landscape modification and rigidly enforced rules governing agriculture, hunting and fishing.⁹

One of the most remarkable of these was the *chinampa* system that at European Conquest supported Aztec and Toltec societies in what is now the Mexico City Basin.¹⁰ Artificially created islands in the shallow bed of Lake Texcoco not only provided most of the food for dense human populations of many millions but also attracted waterfowl and supported fisheries. The Spanish did not understand this system, and deliberately drained most of it in the early 17th century, though the remnants of the system were still able to provide most of the vegetables and a fabulous abundance of commercial flowers for Mexico City's population of about a million people in the late 1930s (Figure 4.2). In the 1980s, Mexico created an ecological reserve in the remaining *chinampas*, very belatedly recognizing the system's unique contributions to agriculture and conservation; though by then the water had been greatly diminished in both quality and quantity. In North America, Native Americans used fire to increase the annual productivity of prairies for bison.¹¹ Along the Amazon, dense populations lived along the river courses governed by traditions that maintained precious fisheries.¹² Whether by draining *chinampas*, systematically killing off the bison population or destroying the traditions and ways of governance that had maintained mostly sustainable systems of human subsistence alongside relatively high levels of biodiversity, Europeans dramatically disrupted biological systems. In most of the places the Europeans encountered, these systems had become co-creations of Nature and human society long before the Europeans arrived.

One of the most powerful effects of the outburst of European trade, discovery, conquest and colonization came about inadvertently. Europeans had long been exposed to a vast array of Old World diseases, some of which had had drastic effects among Europeans, such as the epidemic of bubonic plague in the mid-14th century that wiped out a third to a half of the Eurasian population, from Ireland to the Ganges plain. By the 15th century, European exposure to the epidemic diseases of Africa, Asia and Europe itself had conferred relatively high levels of resistance to these diseases among Europeans. This was not the case for the peoples of the New World who lived in an environment with few if any major epidemic diseases. Europeans took their epidemic diseases to the Americas, resulting in the loss of something like 85 per cent of the indigenous population

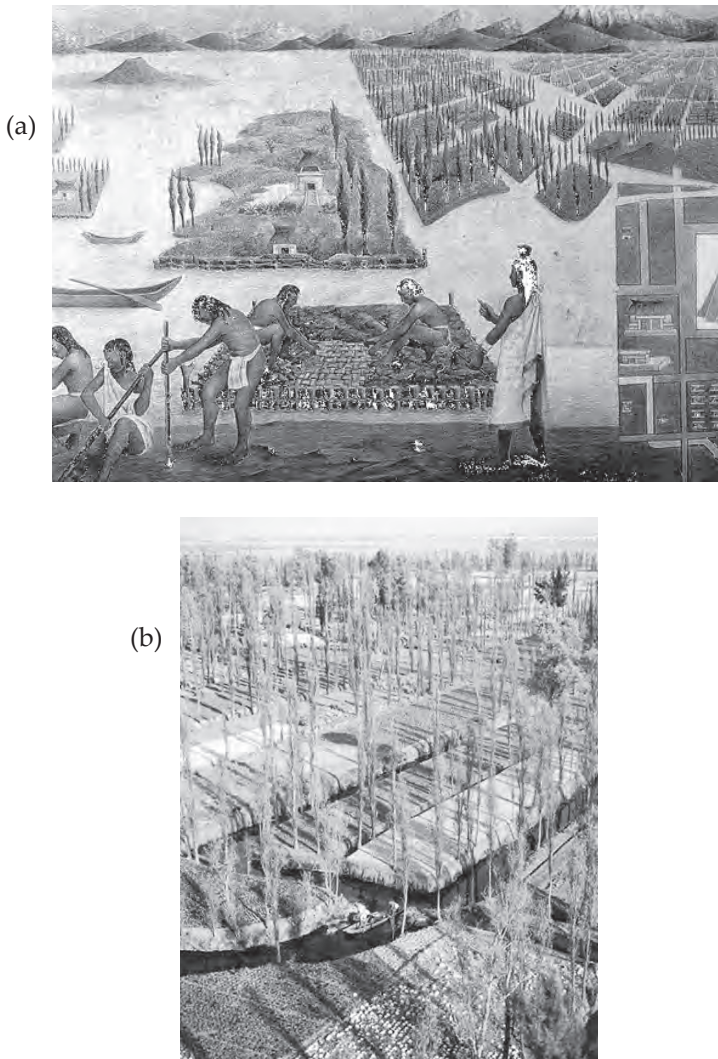


Figure 4.2 Chinampas: (a) drawing of the ancient Aztec chinampas in Tenochtitlan (now Mexico City); (b) modern chinampas in Xochimilco, Mexico

Note: This is an ancient method of agriculture that was practised by the indigenous people of Mesoamerica. Raised beds are constructed with the muck collected from the construction of the canals in shallow lakes. The system is semi-closed in terms of nutrient cycling because the aquatic sector is integrated with the terrestrial sector. The organic matter collected from the aquatic sector is used to fertilize the crops growing on the beds. Nutrients are eventually leached into the canals and are captured by the vegetation and aquatic life living in the canals.

Source: (a) Latin American Studies Program, Rose-Hulman Institute of Technology, Indiana University; (b) Michael Calderwood

within a century or so of initial contact.¹³ This demographic catastrophe was obviously aided by the social dislocation, exclusion from access to land and resources, and outright slaughter that occurred along with it. Mexico would not recover its pre-Conquest population until about 1950 (although the population would quickly double and more due to drastically falling mortality rates resulting from better sanitation, vaccination campaigns and other factors).¹⁴

This seldom meant, however, that plant and animal life would flourish because of the collapse of the human population. As well as transporting human disease, Europeans brought domesticated grazing animals to the New World for the first time, with the exception of llamas and alpacas, which had long been domesticated in the Andes. They also brought the plough. Ploughs and domesticated livestock wreaked havoc on soils throughout the Americas.¹⁵

Europeans also disrupted local traditions and governance. In most areas, they approached the conquered people and lands with a looter's mentality. Their recently developed advanced navigational skills and vast fleets of ships made it possible to ship the loot and produce of the New World on a scale never before imagined. With the corresponding rise of industrial technologies, all of this could be achieved with ever greater speed and efficiency, though at the cost of enormous environmental and human damage in both Europe and the colonial areas. The creation of state-ruled trade organizations and vast private trade enterprises, such as the British East India Company and the Dutch East India Company, established the model for the international corporate organizations that would come to dominate world trade and finance to the present day.¹⁶ This vast technological and organizational machinery created the world in which a small fraction of the world's population, largely in the US and Europe, continue to consume the majority of the world's resources. Part of the same structure arising out of colonialism determines that a majority of the world continues to have access to a minority share of the resources and in economies that are critically and often disastrously dependent on the world's dominant nations.¹⁷

The combination of domesticated grazing animals, the plough, disrupted traditions and governance, and new organizations driven by greed was devastating to diverse environments of the New World. In many regions, the landscapes encountered today bear little resemblance to those first encountered by Europeans. In much of highland Mexico, currently barren, unproductive, arid environments were once areas of abundant agriculture and diverse, lush landscapes. Such is the case with the Mezquital, for example, north of Mexico City, famously subjected to what environmental historian Elinor Melville called 'the plague of sheep', using a term that observers contemporary to the ruin of so much of Mexico's soils had used.¹⁸ Geographer Carl Sauer long ago pointed out that the American Southwest was a far richer environment before the arrival of Spanish agriculture and grazing and the subsequent reshaping wrought

by North American pioneers.¹⁹ Vast forests throughout the Americas fell to European exploitation and settlement. Few regions of the world escaped drastic biological and landscape modification due, at least to a significant degree, to European influence.²⁰

It would not have been possible for Europeans to transform the world without substituting new forms of governance for those they modified or destroyed. In much of the world this meant direct colonial government. In some areas, such as India, it was actually private enterprises, in this case the British East India Company, that exercised direct governing power for long periods of time, eventually to be replaced by direct colonial rule by the British government. The Dutch East India Company long held sway in much of the rest of Asia. In China, political and economic dominance did not depend on direct colonial government but on a variety of treaties and formal and informal arrangements unfavourable to China's interests.

After overthrowing colonial rule by Spain and Portugal, Latin America was mostly dominated by informal political rule and economic dominance by Britain into the 20th century. The same kind of informal power then shifted largely to the US. Until roughly the mid-20th century, this rule was focused on maintaining the conditions to facilitate low-cost economic exploitation of agricultural commodities, minerals and other raw materials exported from Latin America. More recently, the goals have shifted to include maintenance of secure conditions and favourable terms for investment in industrial and service enterprises, including tourism. In Africa, formal colonial rule was largely established in the 19th century to give way to independence in the mid-twentieth, followed by very troubled efforts to establish effective national governments under an overarching framework of neo-colonial exploitation of natural resources. The earth-shaking events of Russia, India, China and Vietnam have been to a significant degree the result of the attempt to shake off control by the centres of power in Europe and the US. In the first half of the 20th century, Japan and Germany vied to attain the power over the world's people and landscapes that had been the privilege largely of the US and Great Britain. The entire history of colonialism and its post-colonial consequences have played a major role in shaping landscapes, from the creation of large mining complexes to the destruction of vast stretches of forest, to the creation of plantations and the displacement of indigenous people onto marginal and fragile lands. The enormous waste of war has been integral to the process as well.²¹ The point here is not to take sides or to make retroactive moral judgements about all the implications of these events. Rather, it is to insist that conservationists recognize that their work is ultimately governed by massive shifts in power and interests that they cannot control but must attempt to understand if their work is to endure. Conservationism without political and historical consciousness cannot hope to be well designed or well positioned.

While Europe and the US imposed exploitive terms on the rest of the world, they also brought ideas that would challenge the regimes of

exploitation. In Latin America, early anti-colonial revolutionaries were inspired by the American and French revolutions and the doctrines of democracy and human rights that underlay them. Movements for an expanded suffrage and democratically accountable government, the abolition of slavery, labour rights, women's rights, socialism, communism and a host of other ideas inevitably influenced the ruled as well as the rulers around the world. As people struggled to gain a degree of autonomy from outside rulers, they were also inspired to look deeply into their own traditions of governance and political struggle, formulating new ideas that combined the European with the indigenous. Gandhi's particular philosophy of militant non-violent struggle is one of the most famous examples, but there are many others including the variants of communist revolutionary struggle developed throughout colonial and post-colonial rule. In India, Gandhi's non-violence, his rejection of the moral character of industrial capitalism, and his reverence for Nature were powerful forces in the Chipko movement, known as 'the tree huggers', in which villagers and allies protected trees from loggers through direct confrontation.²² Beyond Chipko, Gandhi's philosophy and methods have been widely influential around the world in the environmental movement and the movement for land rights for family farms. Chico Mendes in Brazil learned his politics from a formerly prominent socialist in internal exile in the Amazon forest.²³ Wangari Maathai, Nobel prize-winner for her efforts in promoting tree planting and land rights for Kenya's poor, and a worldwide Green Belt movement, worked within the Kenyan women's and labour movements, built from a combination of American, English and Kenyan indigenous roots.²⁴ The Zapatistas of Mexico take much of their inspiration and guidance from indigenous traditions of southern Mexico.²⁵ Conservationists who want to do more than draw boundaries on maps and throw up fences patrolled by armed guards have to try to understand the complex intellectual and political terrain in which they move, just as they must understand the physical and biological landscape.

The Bretton Woods institutions

As World War II drew to a close, the victorious powers began to draw up rules and institutions to govern a new world order when most of the former industrial powers of Europe and Asia lay in ruins. Those among the victors whose economies had been devastated would need financing and other forms of support to rebuild their economies, and it was quickly obvious that the system would be highly unstable and subject to communist revolution if Germany, Italy and Japan were not rebuilt as well. All of the former industrial powers would insist on enjoying some of the fruits of victory along with the US. It was also clear that control over world resources and investment opportunities would no longer be able to depend primarily on direct colonial rule.

At the Bretton Woods conference in New Hampshire in 1944, the Allied nations established a new system for global financial stability that, it was hoped, would avoid a repeat of the disastrous period between the two World Wars. There was a general realization that the origins of the war were mainly economic, including the Great Depression, the complete collapse of the German economy following World War I, and the expansionist desires of both Japan and Germany. To rebuild the industrial nations that lay in ruin, the government representatives at Bretton Woods established the International Bank for Reconstruction and Development (IBRD), known popularly as the World Bank. To avoid the violently disruptive cycles of inflation and deflation that had plagued the inter-war period, the Bretton Woods economists designed a system meant to provide reasonably stable exchange rates. This would be achieved and complemented by the need to promote international monetary cooperation and international trade. The International Monetary Fund (IMF) created at Bretton Woods would be the institution primarily responsible for carrying out these objectives. The World Bank and the IMF were to work closely together to promote economic recovery and stability.²⁶

The Bretton Woods institutions became virtual arms of US foreign policy and played a major role in the strategy of the Cold War waged with the Soviet Union and China. The World Bank was by most accounts strikingly successful at post-war reconstruction in Europe and Japan, and on the basis of this success set out to promote economic development in the world's poorer nations, many of them just emerging from colonial rule. These poorer nations, described at the time as the Third World (neither First World industrial capitalist nor Second World communist), were often attracted to socialism and communism. The US used the IMF and the World Bank in conjunction with a variety of other institutions and programmes to counter what it saw as the threat of communist advance in the Third World. The US built up the largest and most widely dispersed military force in the world, carried out overt and covert interventions to avoid the ascendancy or success of left-leaning governments, offered food and development assistance as political leverage, and sold and gave away massive quantities of armaments along with supportive military and police training to friendly governments. An aggressive diplomacy accompanied all these efforts. The IMF and World Bank were an integral part of this Cold War strategy. By the end of the 1950s their role had shifted almost entirely from post-war reconstruction to Cold War foreign policy implementation.²⁷

The weak economies of the poorer, less-industrialized nations were subject to crisis. The IMF stepped in during many of these crises with a combined programme of bail-out loans to stabilize the currency and 'Structural Adjustment Programs' (SAPs). As a condition of bail-out loans, the IMF nearly always demanded that nations accept significant deflation. This had the effect, among other things, of making raw material and agricultural exports available at cheaper prices to other nations.²⁸ The SAPs

combined deflationary policies with sharp cuts in government spending, lower taxes, reductions in tariff and other trade barriers, increased user fees for basic public services such as public transportation, stagnant or lowered wage rates, and reduced regulatory pressure on investors. The stated goal of currency stabilization was to be achieved through making the countries more attractive to foreign investors and making export products more attractive to foreign buyers. This meant opening the mines and running them at full speed, cutting forests, and converting farmland from local food production to commodity production for international markets. Reduced barriers to trade encouraged consumption of foreign goods by local populations. The essential idea was that the nations in crisis were suffering from an inadequate commitment to developing their resources and an overly protective attitude toward local businesses, farmers and workers. They weren't as eager as they needed to be to sell their resources and labour. They needed to run faster. Were they to run faster, they would earn more and the already wealthy nations would also grow faster as a consequence of access to cheaper resources and more foreign sales to Third World consumers. Faster growth everywhere would be good for all – 'a rising tide lifts all boats'.

The World Bank worked closely with specific IMF programmes during crises, and, consistently with IMF philosophy, between crises. The World Bank concentrated on financing the infrastructure investments that would facilitate the IMF programme. They helped to build roads, dams, electricity networks and other basic infrastructure to make it possible to gain access to and commercialize the nations' resources. The World Bank also planned its investments in close coordination with private investors, attempting wherever possible to use public financing (based on taxpayer contributions in the US and Europe) from the Bank to leverage larger amounts in private capital. To work as planned, the avowedly public-interest purposes of the World Bank and the IMF had to be in concert with the purposes of bank and corporate finance.²⁹

This combined programme did encourage a certain pattern of economic growth, but at the cost of widening inequalities between rich and poor. Whatever its direct economic consequences, however, it was clearly a recipe for creating severe environmental problems. Much of the programme was directly aimed at maximum resource exploitation at cheap prices with a minimum of regulation supported by infrastructure investments that guaranteed wholesale landscape transformation. The flow of resources maintained a downward pressure on their prices and created periodic price volatility while tending in the long run toward resource exhaustion. The work was to be done at as low a wage as possible, and most of the contracted goods and services were to be purchased from foreign firms who would gain a lion's share of the direct investment, which meant that local labour forces would remain relatively untrained and dependent on any kind of economic activity available, including pioneer settlement and forest clearance. The whole programme was carried out in a way that

strengthened specifically those Third World elites who were most interested in maximum immediate profits. Influential capitalists and public officials who were more interested in building stable local markets and more skilled labour forces in a reasonably regulated business environment, taking a longer view of what would serve the interests of their countries, were systematically pushed aside. The political effect was to set up and maintain a vicious economic cycle that required repeated visits of World Bank and IMF officials to keep a fundamentally flawed model of development afloat – all part of what disenchanted World Bank and IMF employees were beginning to call ‘the debt trap’. When conservationists finally began to understand the implications, some international environmental and social justice organizations launched determined campaigns in the late 1980s to reform or eliminate the World Bank and the IMF. The critique has been so successful that today, the World Bank (and to a much lesser extent the IMF) have internalized much of the environmentalist criticism of their former policies, at least rhetorically. However, it remains very much an open question whether they will continue over the longer run to put their money where their mouth is.³⁰

The IMF/World Bank/US foreign policy programme pursued during the last half of the 20th century inspired determined opposition in many nations. One of the central tasks of US foreign policy and military apparatus was to dampen or eliminate such opposition. For most of that time, the justification for US pressure, intimidation, and covert and overt military intervention abroad was the Cold War. However painful the path of capitalist development might be, it was argued, it was certainly preferable in this perspective to socialist and communist approaches, and even to nationalistic capitalist policies. The US carried out violent interventions to enforce this view in one nation after another, including Greece, Iran, Guatemala, Nicaragua, Chile, Argentina, the Dominican Republic, Grenada, Indonesia, the Philippines, Vietnam, the Congo, Angola, Mozambique and many others. In virtually the entire Third World, including Brazil (as discussed below), the US frequently worked closely with selected elements of local elites to subvert democratic processes, whether through secret contributions to friendly parties and candidates, fixed elections or support for military coups.³¹

After the Cold War

The end of the Cold War eliminated the possibility that opponents of US policy might enjoy support from the Soviet Union, and thus also seemingly eliminated much of the justification for intervention. As a consequence, old wine is packaged in new bottles to pursue familiar aims. A programme to promote ‘free’ or ‘liberalized’ trade, and thus generalized ‘globalization’, has been vigorously promoted from Washington since the late 1980s. Putting more emphasis on the importance of eliminating trade barriers, the ‘neo-liberal’ programme, often styled the Washington

Consensus, contains very familiar elements. Government regulation of business activities and a variety of subsidies and policies to support activities considered in the public interest are redefined as barriers to trade to be eliminated or reduced. These can include restrictions on export of capital from poor nations, assistance to farmers, and many kinds of taxes on goods and investments levied to support social spending on education, health care and the environment. The US and sometimes other rich nations exert severe pressures to eliminate such barriers, arguing that generalized economic growth supported by liberalizing trade and investment will eventually provide the right economic and social conditions for universal prosperity and appropriate environmental programmes. At the same time, richer countries including the US have hypocritically maintained barriers to trade of all sorts that serve their own interests.³²

Much of the 'Washington Consensus' is carried forward by the World Trade Organization (WTO), which replaced an older and more limited arrangement known as the General Agreement on Tariffs and Trade (GATT). The WTO is the organ intended to supply the overall supervision and legitimization of the new global order. Unfortunately, the WTO has little transparency or accountability to democratic institutions. Much of its operations are conducted in secret and there is little obligation to explain or justify the organization's actions. It has been largely run by economists allied with large corporate interests and it attends to the neo-liberal model as though it were a law of Nature. It has thus far acted to smooth the way for corporate activities to be carried on without disruption. Most vociferous complaints about the WTO have come from environmentalists and labour groups, and more recently from small farmer organizations which have suffered the most from the brunt of the neo-liberal policies for agriculture.³³

The fly in the ointment emerged in the 1999 meetings of the WTO in Seattle, USA, and then in Cancun, Mexico, in 2003. An international coalition of environmentalists and unionists came out in force to effectively shut down the meetings. Especially at Cancun, from within the meetings a coalition of nations led by China, India, South Africa and Brazil launched a critique of WTO policy that was similar in some respects to the one coming from dissidents outside the hall, pointing out the systematic inconsistencies and contradictions in WTO policies that had the effect of favouring the interests of the rich over the poor. Since these meetings, the WTO has been unable to meet without a retinue of security that makes the whole operation look at best a bit suspicious, at worst like a new brand of fascism. For a decade now it has been impossible for the WTO and the Washington Consensus that energized it to shape any broad new initiatives or agreements. The world economic crisis of late 2008 cast further doubt on the likelihood of advancing the Washington Consensus or of forming a new consensus on anything like similar principles.

Inequalities have widened under the neo-liberal programme. At present, the wealthier nations, which account for about 17 per cent of the

world's population, use about 70 per cent of the world's energy resources. That leaves about 30 per cent of the available energy for the other 83 per cent of the world. The figures are similar for most other resources.³⁴ Some suggest that leaving 83 per cent of the world with only 30 per cent of its goodies is immoral and unfair; others that it is highly unstable and therefore self-defeating. Recent events suggest that the rest of the world will insist on significant changes in a context that is made even more complicated by the problem of global climate change and the eminent end of oil as a basic energy source. Conservationists will find that many of their partners in the tropical world understand this situation and deeply resent it. The problem and the consciousness of the problem invariably condition all international conservation work.

The underlying dynamics of expansionist capitalism combined with the specific programmes for growth and development adopted by the ruling powers after World War II would seem to constitute a reasonable foundation for understanding both the ever more rapid use of the world's resources and the relentless concentration of their use by a minority of the world's population. Careless habitat degradation and the decline of biodiversity follow the same logic. The problems in a sense are not accidental consequences of economic growth but are the accepted price of a well-developed overarching policy.³⁵ In this sense, they are simply part of the plan. Interestingly, much of the conservation community has been slow to see this.

Malthusianism rearing its ugly head again

One of the main factors that has caused confusion has been the lingering popularity of varieties of Malthusian thinking in the conservation community, though it has been largely rejected elsewhere. One kind of traditional conservation agenda has its roots in this primitive Malthusian equation, albeit only tacitly so in most cases. It is taken as an unquestioned assumption that as population grows – frequently leaving it vague as to whether the variable of concern is global or some more regional population density – natural habitat will be 'destroyed', by which is meant, converted to agriculture. With its more humanitarian face, this viewpoint normally adds the idea that these people have to be fed, or they will either die (usually regarded as a bad thing) or encroach yet further on natural habitat (sometimes regarded as even worse). Consequently the problem is presented as a zero-sum game in which every piece of land devoted to agriculture cannot be devoted to conservation. With this fundamental framing, conservation goals include population control, increasing agricultural intensity on already converted lands, and higher vigilance of areas under 'protected' status.³⁶ The paradigm we propose could not be more at odds with this perspective.

A crude Malthusian foundation remains a mainstay of some elements of the conservation community, even though it is rarely articulated explicitly.

Thus, for example, a recent debate about the nature of the deforestation crisis takes as a starting point the size of a local rural population as a driver of deforestation.³⁷ Other examples could be cited, almost all of which are characterized by a simple confusion between correlation and causation (e.g. a deforested area tends to attract more people, thus possibly reversing the implied causation). In all human endeavours there are two, not one, population variables that are relevant to any discussion: first, the size of the minimum population that would be necessary to sustain whatever productive activities are currently the base of the population's existence, whether the production of cars in Detroit or the production of vegetables in Las Lagunas, Mexico; second, the total number of people that can be supported by those productive activities. In the case of Las Lagunas, a complex agricultural system, based essentially on the maintenance of terraces, had long provided a comfortable and sustainable food supply to the local community, which is to say the productive activities sustained the population. In the late 1970s, with a new oil industry booming in a neighbouring state, a large fraction of the males in the community migrated to take jobs in the new industry. The population decline was substantial enough that the maintenance activities required to keep the terrace-based agricultural system operative could not be met. Because of migration, the actual population fell below the population necessary for maintenance of the productive system. Consequently, the agricultural system collapsed and the previously well-fed population suddenly went to bed hungry – the agricultural system could no longer sustain the extant population.³⁸ In the case of all human productive activity there is a minimal number of people required to maintain productive capacity and a critical number of people that the productive capacity can sustain. Any population, regardless of its actual per hectare population density, can be either relatively overpopulated or relatively under-populated, depending on what level of technology is under consideration. The current population of Japan could never sustain itself without its modern productive systems, all of which are based on a large number of people; while the island nation of Madagascar, about the same size as Japan, could never sustain the population of Japan with its current productive system. Yet Madagascar could not build the sort of productive capacity of Japan with its comparatively lower population and thus is an under-populated island, from this point of view.

Beyond the crude assumptions of Malthus, the apparently humanitarian notion that we must feed the world's population leads to the assertion that we need to intensify current agricultural areas. The first problem with this assertion is that the world produces an enormous quantity of food already, and has done so since the British withheld food stores from its starving client states in Ireland, India and China, to name a few.³⁹ Indeed, there are few known cases of massive human famines that occurred without export of food away from the famine victims.⁴⁰ In the contemporary world we already produce so much food that the main problem faced by farmers is lowered prices because of an excess of supply.⁴¹ The reason people go to

bed hungry every night has nothing to do with the food supply – rather they have been excluded from land to produce their own and cannot afford food offered on the market, or because of war and political disturbances that block access.

The assumption that the elementary structure of the assumed zero-sum game can be easily manipulated by the intensification of agriculture, especially in areas on agricultural frontiers, is perhaps the most dangerous and egregiously false of the conventional assumptions.⁴² Angelsen and Kaimowitz provide a series of case studies based on their initial formulation of the contradictory nature of the claims of conservationists and the standard assumption of development economists. If anything, the intensification of agriculture, if not done in a cautious fashion, is likely to increase the local pressure on natural habitat.⁴³

On the other hand it is not crude Malthusianism to assert correctly that in a general sense growing human numbers do potentially put additional pressure on world resources and environments. But that assertion does not go very far in understanding the complex circumstances that drive population growth and decline, nor does it go far in understanding the highly variable effects of human numbers on agricultural production and Nature. Human population growth is responsive to social factors, and its effect on species and habitats are fundamentally conditioned by social organization and technological choices. The conservation community needs to get beyond Malthusianism. For we will see in the section that follows how inaccurate and dangerous it can be.

What we have done here is to present a view of the world and its recent history emphasizing elements that strongly condition all efforts to preserve species and habitats. We move now to a consideration of more specific problems of conservation work, and to a review of how those have played out in the context of the Brazilian Amazon: the world's overwhelmingly largest and most diverse reservoir of species. Here we will see the broad issues of the context discussed above in action.

DIFFICULT SOCIO-POLITICAL ISSUES IN PRACTICAL CONSERVATION WORK

It is not a simple matter to assess the relationship of an existing or potential protected area with respect to the influence of the agricultural landscapes that surround it. An ecologist can be exceptionally well qualified to evaluate the biological character of a relatively wild landscape while at the same time being poorly trained to understand agricultural landscapes in the same region. Just as importantly, conservation biologists and other experts may make important errors in understanding how the agricultural areas surrounding a protected area developed historically, and therefore may be unable to accurately judge whether the quality of the relevant agricultural matrix is likely to remain as it is, deteriorate or improve.

Imagine a conservationist looking outside the borders of a protected area in the tropics, actual or potential, towards surrounding agricultural areas. She observes people living in roughly constructed houses working on the land. The houses or groups of houses are scattered through what the conservationist sees as a 'disturbed forest'. There is a patchwork of fields devoted to various crops. In some areas are stands of forest that resemble the undisturbed forest within the protected areas, and there are areas that have some of the trees and other plants of the undisturbed forest, but the biologist observes many plants seldom seen within relatively undisturbed areas. Other areas are characterized by some combination of weedy, invasive annual plants, some perennial legumes and grasses, and a few shrubs. Local farmers cut and burn in some places, and may clear new fields within what looks like undisturbed forest.

The first problem of interpretation in this example is to understand where the process of human use of the landscape has been and where it is going. There is a strong tendency to see such landscapes as frontiers in which undisturbed forests are being degraded by either new migrants into the region, localized population growth, or progressive environmental degradation over time by a resident population, or as a combination of all three. This may be correct. Or, in contrast, it may be that the people of the area have been here for a long time – anywhere from decades to millennia – in a stable relationship with the resources and organisms in the area. In this case, the pattern made up of a combination of land that is actively farmed, land of relatively undisturbed forest, and land in various stages of succession between human disturbance and recovery toward a high level of diversity resembling the original forest is a pattern that could have been observed here for much or all of the period of human occupation of the region. Disturbance is a constant, but so is the cyclical process of recovery and various stages of succession from farming to forest and back again. It may be a cycle in which the net amount of land experiencing disturbance versus that in recovery is relatively stable. The cyclical pattern may be supportive of a fairly high level of biodiversity within the agricultural landscape and an even higher level than within neighbouring undisturbed areas.

In many regions it will be difficult to tell the difference between frontier and long-term occupation simply by a snap-shot observation. One will have to consult the historical record. In order to ensure reasonable accuracy, researchers will have to examine written archival sources, interview local people and government officials, and carefully examine the land and its biota in detail. Making sense of the record is often far more difficult than one might imagine. It can usually be taken for granted that the evidence will not only be complex but it will often appear to be contradictory. It will be necessary to have a high level of skill to incorporate historical, anthropological, agronomic and biological knowledge into an accurate interpretation. Making a mistake in this regard could be fatal to conservation efforts.

If the region is undergoing active frontier occupation or progressive deterioration from the actions of a resident population, the observed pattern might mean that if things keep going as they are, forest remnants and areas of recovery will become successively more scarce and smaller in area. Biodiversity both outside and inside the protected zone is likely to suffer, perhaps drastically. This kind of situation is common in tropical rainforest regions throughout the humid tropics. It may be found in the Amazon, in Central America, Africa, India and Southeast Asia. In most areas where frontiers of human settlement are pushing insistently into the forest, conservationists face one particular set of very difficult dilemmas. How will it be possible to stop or, more likely, limit the impact of frontier development on the agricultural landscape with all of its implications for any protected areas? Stated in its simplest form, conservationists will have to devise a way to sweep back or channel a powerful tide that is running against their own efforts. In its more complicated forms, any real hope for conservation within reserves will require that somehow there will be effective ways to deal with gut-wrenching issues involving social inequality, political power, exploitation, manipulation, corruption, and large-scale environmental and demographic change.⁴⁴

It is also important to understand the motivation and organization of people in the region. This is likely to involve some quite complex considerations, but at the simplest level it is obvious that if frontier settlers are being given incentives by governments and/or businesses to move into an area, the problem is quite different than if the new settlers are simply individuals in search of new farmland. If, as is frequently the case in the Amazon and other tropical areas, frontier settlement is strongly driven by the eagerness of timber companies to enlist the settlers' labour in felling trees and clearing roads, then the conservation problem will not be solved if that fact is not appreciated and addressed. If further, as is also common in the Amazon, powerful and wealthy ranchers are eager to acquire land exhausted from crop production, another key factor is added. If the ranchers are willing, as they are in the Amazon and much of the rest of the tropics, to encourage settlers to clear land and then further willing and able to drive settlers off the newly cleared land by legal manipulations, corruption, intimidation and violence, then the situation becomes yet more complicated and difficult. If mining or other extractive interests are also involved the situation becomes even more complex. This is the case in much of the Amazon and Africa, where people are lured to the region by the prospect of mineral prospecting or employment in mines and then are periodically laid off and forced to make a living from agriculture, sometimes only to be drawn back to mining in a cycle of employment alternating between mining and farming.

The character of agricultural activity may also be influenced strongly by whether settlers are acting completely as individuals or single families, or whether they are organized by informal groupings from prior associations in other locations (as towns and villages outside of the forest region may

be more or less reconstituted in new agricultural areas or in urban slums), or whether they are organized by rural unions or land associations.⁴⁵ If the government encourages settlers through land distribution and titling, credit, extension services and incentives for housing construction or crop production, the situation will be very different than if government does not provide support. Government may also be relatively effective or ineffective at enforcing the law, either in support of or against settlers' interests. Supportive services and law enforcement can be either positive or negative in terms of habitat and species protection, depending on how they are designed and implemented.

Some frontier settlement is done by settlers with virtually no experience with the ecological details of the region, as they often come, for example, from highland plateaus or more arid regions into humid forests. They may, however, bring with them a great deal of relevant knowledge and experience as prior forest dwellers or traditional agriculturalists. They may be relatively well equipped to experiment and learn, or very poorly prepared to do so.

The likelihood of adaptation to the new environment will be strongly influenced by whether they are organized into rural unions, cooperatives or land reform movements, and by the ideology and strength of those movements. Some rural organizations are strongly focused on advocacy for settlers with little or no interest in adaptation of agriculture towards sustainability in the frontier region. Other more sophisticated organizations are strongly aware of the difficulties of both new and established settlers and are actively engaged in a variety of ways to ensure that settlers are able to achieve sustainability in their new farms. These latter organizations are also likely to be more interested and effective in working with conservationists towards the compatibility of protected areas.⁴⁶ This is true, as we will argue below, for some both obvious and not-so-obvious reasons.

If the patterns observed in the region do not involve significant frontier settlement but rather are the established and stable ones of a long-term resident population, then human settlement and farming may prove to be supportive of the effort to maintain high levels of biodiversity inside and outside the protected area, as species move in and through the agricultural matrix as well as within the protected areas. In these cases, it may be possible to achieve a great deal simply through recognizing the positive contributions of existing patterns of settlement and agricultural activity, and it may prove fruitful and relatively easy to encourage initiatives that will go further to actually strengthen the relationship between the goals of conservationists and those of farmers or peasants in the region. These situations are also common in many areas of the tropics. Again, the degree of success in this regard is likely to be determined by many of the same cultural, organizational, economic and legal factors as those that influence new settlers.

SOURCES OF SYSTEMATIC BIAS IN CONSERVATION PRACTICE

Unfortunately, whether involving new settlers or established residents, many situations are misunderstood for their conservation potential because of a powerful bias among conservationists, government policy-makers, agricultural scientists, agronomists and ecologists. From a synthesis of the research, much of it cited above, and from our own experience over four decades and in several countries, we can summarize this bias as it works at eight critical levels:

- 1 The powerful desire to maintain high levels of biodiversity in relatively undisturbed areas has led many people, including and sometimes especially those with high levels of biological expertise, to regard all kinds of agriculture as dangerous to conservation efforts. They simply do not appreciate the critical differences between various kinds of agriculture in terms of their potential to support conservation.
- 2 Many agricultural scientists and agronomists trained in conventional agricultural methods see the kind of agriculture that is often practised by forest dwellers, indigenous people and small-scale farmers as hopelessly inefficient, unproductive or unworthy of study or respect.
- 3 Conservationists are often best acquainted with the formally educated and socially prominent elites of a region both by personal preference and as a necessity for influencing government policy. These local elites may be strongly biased against poorer rural populations, their culture, their organizations and their interests. The elites will pass on their biases to conservationists in myriad direct and indirect ways, and they will act vigorously to protect their interests against assertions and initiatives by the poor. Deep prejudices against the poor are also sometimes found embedded within conservation organizations themselves and find ready reinforcement from elites at various levels.
- 4 Lack of language skills and/or cultural understanding creates a serious gap between those involved in conservation and agricultural development and the people engaged in agriculture. This is likely to be especially true where the people farming belong to groups with well-established traditions and strong group identity: precisely those who are most likely to be farming with sophisticated traditions of local knowledge that are culturally evolved to adapt to the landscape in a sustainable way.
- 5 Policy-makers and conservationists often lack an understanding of the dynamic nature of what they are observing – they are eager to solve problems as they appear in the present and are impatient with historical analysis that may be necessary to understand the forces and trends that are driving land use in particular directions. Analysis of the present situation is systematically privileged over attempts to

understand the arc of historical change. This is likely to lead to poorly designed policies.

- 6 As the present is privileged over history, so may analysis of local circumstances be privileged over understanding the larger regional, national and international context. Again, the results can be quite troublesome.
- 7 Conservationists may lack the knowledge and willingness to engage in teamwork across science and social science disciplines that are usually necessary to investigate the situation properly, draw accurate conclusions and make useful recommendations.
- 8 Conservationists often apply some version of Malthusian analysis to environmental problems, often inappropriately. It is all too easy, and often severely misleading, to see biodiversity conservation as simply a function of insistently rising human numbers relentlessly destroying habitats and species.

THE BRAZILIAN AMAZON: A CASE STUDY IN CONSERVATION, LIVELIHOOD AND SOCIAL MOVEMENTS

A case study that summarizes all of the above can be seen in a review of major conservation efforts in the Brazilian Amazon over the last several decades – efforts meant to slow deforestation and establish effectively protected reserves for habitat and species conservation. The Brazilian Amazon has rightly been the focus of immense effort on the part of the international conservation community and a subject of intense controversy and debate within Brazil. The story is far too long and complicated to tell in detail here. A brief review, however, brings out the dangers of all of the sources of systematic bias identified above.⁴⁷

The variety of human activities

For many years (roughly from the 1960s to sometime in the 1980s, with some conservationists and their organizations still stuck in these habits to the present day) most conservationists in the region failed to undertake any serious evaluation of the differences among types of human settlement in the region, essentially working to reduce activity in the Amazon forest everywhere and in all circumstances. This was an impossible and self-defeating task. They failed to achieve their objective and made enemies of nearly everyone. The one significant exception was for long-established indigenous people, and even in this case, conservationists did relatively little at first to reach a profound understanding of the dynamic character of indigenous life and its effect on the forest, preferring instead to see the indigenous people of the Amazon as essentially frozen in time. Indigenous people were seen as static, having no history of change in

regard to their effect on the forest and having no future other than a stark choice between elimination or preservation, essentially as living cultural museums. Indigenous people were too often seen as lacking the ability and sometimes even the right to make autonomous decisions. Such attitudes were radically at odds with what is known about Amazon indigenous groups, who have undergone dramatic changes over the last 500 years, and who continue to change. For example, recent research has increasingly supported the view (as reported by the first European observers in the region and later discounted) that the Amazon supported populations much larger than previously supposed, living essentially in long cities stretched along the rivers. The population may have been as high as the present population of the Amazon region. In any case, it is clear that the scourge of European disease and European enslavement of Amazonian indigenous people forced them to retreat into the forest and away from major waterways that attracted Europeans. The retreat from the areas along major rivers, which are usually the most promising areas for human foraging, fishing, hunting and agriculture, forced indigenous people to adopt new and more difficult survival strategies. In one version of this view, Amazon indigenous people are still in the process of sorting out the consequences of a way of life that, prior to European contact, was much easier and more prosperous. In the present era, indigenous people are increasingly influenced by recent incursions of settlers and economic enterprises, and are challenged again to work out new means of survival. They are not 'museum' cultures, but rather cultures that have for 500 years been dealing with the challenge of living within a context that has been getting narrower, more complex and more difficult over time. In most instances, they are not a set of peoples living in glorious isolation until recent encounter, but rather a set of people engaged in a very complex pattern of strategic retreat, periodic contact, partial assimilation, disastrous exploitation and exposure to Old World disease.⁴⁸

The consequences of failing to understand the enormous complexity were mostly bad for indigenous people and bad for the cause of conservation. Disregarding, idealizing and attempting to freeze indigenous people within a particular way of life were all responses based on ignorance. This was true in spite of the fact that Brazilian and foreign anthropologists had for many decades been creating a rich literature on Brazilian indigenous people that, if understood, would have avoided such mistakes.

Perhaps even more serious for the cause of conservation, as well as for the welfare of Amazonian peoples, was the tendency to overlook the differences in subsistence strategies among non-indigenous inhabitants. Some of these were recent settlers and some had several generations of experience in the Amazon. The cultural, physical and ethnic boundaries between many of these people and indigenous people were often so blurred as to be insignificant. (Inter-marriage and two-way cultural assimilation have made the word 'Indian' or 'indigenous' difficult and slippery terms in the Amazon – when visitors say they want to 'visit the Indians', locals

know that what the visitors want is a kind of artificial museum experience that in most instances is faintly related to cultural realities in the region, but locals will often attempt to oblige by creating a satisfying experience in the interests of courtesy or money.) Some of these people moved across the landscape, relentlessly cutting forest and exhausting soils, providing trees to the timber industry as they cleared land, inadvertently or intentionally, for predatory and unsustainable ranching operations. In sharp contrast, many others established relatively stable communities, practising a livelihood that included agriculture, fishing, hunting and gathering in a way that was consistent with high levels of biodiversity conservation. Such communities often protested vigorously against wholesale forest destruction and sometimes stopped the timber and mining industries from further forest encroachment. A large share of Amazon people lived lives that alternated between extremes of destructive work on one hand and livelihoods based on conservation practices on the other, which also often involved moving back and forth between city and country. This is still the case. Most people who live either temporarily or permanently in rural areas are in search of permanent homes and communities and in need of sustainable practices that would support permanence.⁴⁹ It has to be noted here that the Amazon population as a whole is one of the most urbanized in Latin America, with more than 80 per cent living in cities. This also has very important implications that we will not try to explore here.⁵⁰

In 1978, we heard one of the most passionate and knowledgeable talks we have ever heard on the need for forest protection and what was required to achieve it from a man employed as a bulldozer driver whose machine was fitted with long chains attached to another bulldozer for the purpose of literally mowing down trees in vast swathes. What made it remarkable was the machine operator's intimate and subtle understanding of the interplay of various economic and political interests at work in the region. At that time and to the present, even those making their living from wholesale forest destruction sometimes understood far better than conservationists the dynamics of forest destruction, and yearned for the conditions and policies that would make it possible to have livelihoods consistent with forest protection.

Major international conservation groups, most prominently what was then the World Wildlife Fund (WWF, now known as the World Wide Fund for Nature), demonstrated their lack of understanding of the nature of the problem in their collaboration with Brazil's military government in a vast development scheme along the Amazon's southern border. The project was planned in the late 1970s and initiated in 1981. The military, heavily financed by the World Bank, envisioned a typically technocratic and authoritarian approach to the problems that were being encountered in the Amazon in what they called The Polo Noroeste Project. The WWF and some other conservation groups and individual conservationists had decided that it was better to attempt to cooperate with the Brazilian government than

merely to oppose it. The elaborate plan would theoretically protect a large part of the region's forest and its key biological resources. The plan called for strictly limiting road-building, the number of new settlers allowed into the region, the amount of timber cutting, and the extent of ranches. It would protect indigenous people from settlers, and forest reserves would be strictly delimited and guarded.⁵¹

The plan quickly went awry. Land speculators, settlers, ranchers and the government's own officials virtually ignored the plan. The government continued to support infrastructure development, most importantly road-building, while failing to enforce conservation laws. This should not have been surprising, since the very interests that supported the military were the same ones that were so avid to have access to the Amazon's resources. Conservationists had been persuaded that the military's technocratic approach combined with its hard-fisted ability to stamp out opposition to its will would mean the plan would succeed. They did not understand that the application of the hard fist would be exercised to promote various financial and corporate interests and against the interests of the poor and the forest. Conservationists had been seduced by the military's claim to technocratic efficiency and consistency, not realizing, as one would expect of anyone with long experience in Latin America, that the power of military regimes is nearly always exercised on behalf of various national and international economic interest groups who are the military's base of support.⁵²

Many conservationists at this point privately lamented that the problem had been the implacable force of the wave of desperately poor immigrants into the region. They were often made vulnerable to this position by their implicit or explicit Malthusianism – a view largely discredited in economics and the social sciences but that still has a lively place in the minds of many biologically trained people. What they saw was a very rapid growth rate in human population in Brazil, that in the early 1970s had approached a 3.4 per cent annual growth rate, in itself certainly a cause for alarm. What they did not see was that rural poverty in Brazil, according to nearly every serious analyst of the problem, came from massively unequal access to land and resources combined with a corrupt and violent rule by major landowners and their political allies. As ecologist William Durham has put it, in a rigorously theoretical and mathematical analysis of the case of the much more densely settled tiny nation of El Salvador, this was a case of competitive exclusion and not a case of overpopulation.⁵³ Neither did they see that it was poverty, inequality, repression and lack of education that kept birth rates high even when death rates had fallen dramatically. Most conservationists were largely unaware at this point that Brazil had agricultural land sufficient to support the rural population in dignified livelihoods, as it still does. And in the 1970s they were unaware, as were most people including many professional demographers, that birth rates were about to fall dramatically to below one child per woman by the end of the century, with population growth rates as a whole slowing. Overall

positive population growth rates were maintained with fertility rates lower than replacement rates, only by the age structure that determined that young people near or in their reproductive years were a disproportionate share of the population. Birth rates were to fall as a consequence of loosened restrictions on birth control information, pills and devices, along with positive campaigns for family planning that were put in place as the reactionary military regime lost influence. Even more importantly, they fell as a function of urbanization, education and the growth of both rights and education for women in particular, as was the case in most of the world. The Malthusian view that the Amazon was being chewed up by the population's propensity to expand beyond resources available was not an accurate analysis at the time of the Polo Noroeste Project, and it is even less viable as an explanation of the Amazon dilemma today.⁵⁴

Conservationists could not allow themselves to see that they had been suckered into participation in a fundamentally corrupt development scheme just as the settlers were being suckered into the region by false promises of wealth, livelihood and secure landholdings. The Polo Noroeste Project left many prominent conservationists demoralized and more confused than ever about what was actually going on in the region and, in particular, about the complicated role of both long-established settlers and pioneers. On the positive side, more people in the conservation community did begin to think less in terms of implementation through authoritarian government and more in terms of the need for popular support for their objectives. They became more willing to begin the task of understanding the people of the Amazon forest.⁵⁵

Emergence of the *ribeirinhos*

What came to be known as 'the rubber-tappers' movement, led by Chico Mendes, eventually brought some conservationists to see that not all settlers in the Amazon were the same in terms of their impact on the forest. Mendes and his followers did not begin their fight as 'environmentalists' or 'conservationists', but rather as people seeking rights to land: the eternal quest of the Brazilian rural poor. Many of the rubber-tappers and their allies were only part-time or occasional rubber-tappers – a better term might have been *ribeirinhos*, or river people. People living along rivers had worked out combinations of small-scale agriculture, hunting, fishing and gathering of forest products, including latex for rubber, that were relatively compatible with forest conservation (Figure 4.3). While they had worked out viable livelihoods, most of these people were desperately poor and had been viciously exploited for a century and more by middlemen who sold their products downriver. In many cases, they were being newly pressured by an advancing frontier of new outside settlers, ranchers, timber firms, mining companies and government officials, including, at times, conservation officers of the government and supportive conservation organizations. The argument for the rubber-tappers as environmentalists



Figure 4.3 *Houses and settlements of Brazilian ribeirinho people, near Belém, Pará*

Note: Typically, this type of settlement incorporates a variety of perennial tree crops, such as the *acai* palm (seen here) along with *piçava* palms (from which is harvested a high-value fibre), bananas, various tropical fruits and other native trees. Fishing and sometimes hunting and rubber gathering are important elements of household economies, and in this area, *ribeirinho* children receive free public schooling and health care.

Source: Angus Wright

developed out of confrontation and eventual dialogue between rubber-tappers, new migrants, conservationists and government officials. They had the help of some very capable Brazilian and North American anthropologists. It began to emerge that river dwellers and conservationists shared many goals in their desire to slow or stop the advance of both old and new forms of exploitation of people and land.⁵⁶

The formation of an alliance among forest dwellers, mostly working under the loose rubric of 'rubber-tappers', constituted a great advance for the cause of Amazon forest conservation. It made it possible for conservationists to shed their image, and sometimes their practice, as enemies of the poor. As long as they were seen as the enemies of the poor they would be opposed by the majority of Brazilians. Worse, in terms of strategic losses, conservationists would also be subject to cynical and highly effective attacks by investor and business interests who were able to exploit the perceived opposition between mostly foreign conservation organizations and the majority of the Brazilian people. Tying the fight against deforestation to the fight by and on behalf of the poor was successful

to a considerable degree. The positive link between conservation and the welfare of the poor changed the nature of the debate and of political battles fought over conservation at the regional, national and international level.

Beyond debates and battles, the alliance between those in the Amazon who had established relatively sustainable livelihoods in and on the edges of the forest made it possible at last to formulate a credible programme for battling deforestation. It was obvious to virtually everyone, including most conservationists, that protected areas would end up protecting little in the way of habitat and species if they were seen simply as excluding Brazilians from using their own resources for the improvement of human welfare. The poor would not respect boundaries where they saw little reason to do so, and where survival was at stake. The vast distances and difficulty of travel would make effective enforcement impossible. Even more importantly, the powerful tradition of legal impunity for the rich and powerful in Brazilian rural life meant that reserves would be violated systematically by ranchers, timber companies and mining corporations working under the cover of the claim to be contributing to 'national development' in terms of creation of government revenues and jobs. The fact that the most powerful of these extractive resource companies were international corporations with no particular long-term interest in Brazilian development was glossed over successfully. Even where law enforcement personnel were determined, skilled and incorruptible, they were always stretched extremely thin and relied on the active aid and support of the local population – support they would never have if the cause of conservation was identified as opposed to the interests of the majority. The alliance between conservationists and organizations representing the poor was absolutely critical to overcoming these obstacles.⁵⁷

As this alliance was forming, a new appreciation for the role of poor people in forest conservation began to become better known. Conservationists began to recognize that it was almost exclusively the rubber-tappers, indigenous people and small-scale agriculturalists who actively risked their lives in collective actions to oppose wholesale deforestation. It was they who were most aware of violations of forest laws, it was they who put pressure on police to take action and it was they who put their lives literally on the line in blockades against logging operations. When conservationists began to see the value of these activities, they were able to bring national and international attention to them, imaginatively creating films, television programmes, and fund-raising campaigns. Anthropologists helped by teaching indigenous groups such as the Kayapo how to make their own films with hand-held cameras and how to create effective media events – including one in which a Kayapo leader symbolically placed a spear against the throat of a high official of the World Bank in a public meeting. Small bands of urban conservationists involved in forest blockades made little impression on anyone. It was only with the clear and active participation of poor peoples' organizations that these activities could gain traction.⁵⁸

The idea of 'extractive reserves'

One of the fruits of the new alliance was the creation of 'extractive reserves' as a new category under Brazilian law. These reserves would allow rubber-tapping, gathering of wild fruits and Brazil nuts, fishing, hunting, and other activities considered compatible with overall long-term viability of the forest and a high degree of species conservation. Small-scale agricultural activities that did not involve massive forest clearing would also be allowed. Considerable effort by conservation groups went into the support of such presumably sustainable activities as bee keeping. Enormous 'extractive reserves' created under Brazilian law allowed for creative partnership between conservationists and the poor, literally 'on the ground'. Without doubt, the creation of 'extractive reserves' constituted a quantum leap in conservationist thought and practice, internationally as well as in Brazil.

The 'extractive reserve' concept alerted conservationists to the necessity of overcoming many of the eight systematic biases identified above. It became clear that it was necessary to examine human activities in and around forest reserves with a more discriminating eye. Not all agriculture was equally destructive, and considered within the wider context of the biodiversity conservation project as a whole, some agriculture and other activities could be considered supportive of the broad purpose of conservation programmes. There was a necessary recognition that agriculture could not be judged simply by its overall productivity, but by its meaning within a context of multiple human purposes, including conservation. Poor people were seen with fresh eyes, not simply through the narrow perspective of local and international elites. The necessity for conservationists to work to overcome cultural and language obstacles became obvious. To some degree, the importance of interdisciplinary training and cross-disciplinary teamwork became clearer. Conservationists began to have enough experience in Brazil and enough knowledge of its resources and social dynamics to see that the problem of the Amazon was clearly not in its most important aspects a Malthusian case of human populations expanding beyond the limits of available resources. The Brazilian 'extractive reserve' experience did not do away with these systematic biases in conservation work, but it began a process that is still evolving in a positive direction.⁵⁹

Unfortunately, the 'extractive reserves' also revealed critical problems in the specific strategy, which in turn made it clear that some of the systematic biases were still at work among those who had not foreseen these failings. Had the problems been more clearly seen, it would not necessarily have been easy to design a strategy that would have overcome them. It would, however, have broadened the conservationist agenda, particularly at the national and international level, and it would have made it possible to some degree to anticipate and reduce the impact of some of the problems at the local and regional levels in Brazil.

As experience with 'extractive reserves' accumulated, several problems with them began to emerge. The most basic was that rubber-tappers and river dwellers, *ribeirinhos*, had always been very poor and highly exploited people and would remain so after the creation of 'extractive reserves'. The activities they used to support themselves were economically marginal, which is to say, with very little surplus available beyond subsistence needs. But while marginal, these were livelihoods that were partially and critically dependent on national and international markets. It was essential to earn cash, though the amounts might be small, beyond subsistence needs. Rubber, Brazil nuts, palm nuts, various marketable fruits, *piassava* fibre, and other emblematic products of the Amazon river peoples' livelihoods were dependent on national and international market demand. This demand was both limited and fluctuating. As the markets for extractive products were promoted by conservationists and government, they had an additional tendency towards saturation, such that early successes in the 'extractive reserves' often brought disappointment over time. For example, as the 'extractive reserves' were successful in increasing the harvest of Brazil nuts, the markets began to offer lower prices that undermined the entire strategy. These markets were also operated by middlemen, many of them working under the infamous *aviamento* system of usurious credit and company stores, who ensured that when market demand was high, most of the benefit went to them, and when it was low, the effects were largely felt by the *ribeirinhos*. This relationship between producers and merchants was frequently enforced by violence, as it had been for centuries. The government lacked either the will or the ability to put a stop to it. Similarly, the violence exercised by ranchers and timber and mining operators, responsible for the assassination of Chico Mendes in 1988, did not end with Mendes's death nor with the creation of 'extractive reserves'. Shifts in economic growth rates in China and India, and changes in technological choices made with respect to the ratio of natural to synthetic rubber used in products manufactured abroad could and did have serious negative effects on rubber-tappers. The creation of 'extractive reserves' did not put an end to such difficulties, and in some cases may have reinforced them through market saturation. Many extractive communities that were meant to be the heart of the conservation efforts struggled to maintain themselves and were forced to engage in timber cutting and exploitation of forest resources beyond sustainable limits.⁶⁰

It was also naïve to assume, as conservationists often did, that the *ribeirinhos* lived in isolation from the corruption rife in local and national politics. So, for example, grants and subsidies meant to support such activities as bee keeping and aquaculture often ended up in the hands of local political parties and bosses. Another issue arose with regard to the high levels of responsibility and authority granted to municipal governments under the new Brazilian Constitution of 1988. This meant that the success of 'extractive reserves' would depend considerably on both state and municipal government backing for the programmes, in a

context where some of these more local governments were supportive of the extractive reserve programmes and others were outright hostile. There were also serious complaints that the national and international conservation organizations tended to control the policies dealing with the reserves and that they were more interested in conservation and favourable publicity than the need for livelihood. Many of the grass roots organizations, including Chico Mendes's rubber-tappers' union, were strongly interested in acquiring land titles and not merely access to reserve land, while conservation organizations were less interested in or were opposed to granting title to poor people in the Amazon. This conflict has created ongoing tensions and misunderstanding. Also, since much of the loan and grant money meant to support local livelihoods in innovative ways came from international conservation organizations, *ribeirinhos* and rubber-tappers became subject to such problems as 'donor fatigue', the tendency for donors to conservation organizations to lose interest in particular issues after a time, seeking excitement and stimulation in new strategies and causes.⁶¹

During the first decade of the extractive reserve programme, Brazil was also struggling to stabilize its economy. This meant that money for all government programmes was subject to frequent cut-backs. The Presidential administration of Fernando Henrique Cardoso was committed to working within what was then called 'The Washington Consensus', which meant reducing barriers to trade and investment, minimizing government regulation of business activities, and exercising severe budget austerity. Specific policies based on these broad commitments had a variety of implications that tended to increase pressures for Amazon deforestation. 'Neo-liberal' policies promoted rapid growth in export income, most easily obtainable by simple resource extraction because mining and lumber operations required relatively little capital investment. Austere budgets meant that funds for conservation planning and enforcement were scarce. Illegal deforestation continued apace inside and outside of 'extractive reserves' and other protected areas. The traditional legal structure and law enforcement agencies continued to work effectively to protect the middlemen, timber and mining companies, and ranchers. In contrast, the new conservation laws and agencies meant to protect the interests of communities of poor people in the 'extractive reserves' were under-funded and relatively weak. These problems continue under a more socially and conservation-minded government led by President Luis Inácio Lula da Silva that is still committed, if not quite so firmly, to neo-liberal policies.⁶²

All these problems that would arise in the extractive reserve initiative could have been and mostly were foreseen by those with a reasonably deep understanding of Brazilian life and politics, and of national and international economics and markets. Such people had less influence on the extractive reserve programme than they might have had because of their impatience to do something positive about Amazon deforestation. But history and large-scale context did matter and needed to be understood

to avoid undermining the programme and seriously discrediting it in the eyes of many participants and observers.

In fairness it must be said that some of those involved did to some extent appreciate the potential for these difficulties. It was understandable that they would downplay them in order to gain three steps forward even if it might mean taking two steps back. However, the cost was not only felt in the two steps back, but in the general demoralization that has ensued in some places as problems arose. This problem may in the long run prove extremely serious in blunting the momentum of conservation politics in the Amazon specifically, and in deflating the potential for larger-scale political change both in Brazil and internationally. Overselling an idea always runs serious risks. It was also the case that many of the conservationists were caught off guard by the problems that arose in the 'extractive reserves'. Some still operate with their blinkers on because they cannot bring themselves to face the truth. Many have jobs or CVs that will suffer if the matter is discussed more dispassionately. Such considerations aside, it is also clear that if the extractive reserve scheme had been examined with a greater attention to the implications of deeply rooted historical factors and the national and international context, there would probably have been ways of designing it better, and there would certainly have been more realistic expectations about its promise and limitations.

A positive result of the earlier failure in the Polo Noroeste Project was that some conservationists did learn that they needed the support of grass roots movements in the regions in which they operated. This contributed to their willingness to join with the rubber-tappers in trying to create an alternative. However, as we have seen, they had still not entirely learned how complex and challenging the problems of conservation in the Amazon could be. They tended to romanticize the rubber-tappers and indigenous people and did not face up to how severely constrained these people were by economic and political realities in a context of a fundamentally corrupt legal system that had been designed to serve the interests of those who controlled national and international markets. Conservationists seem to have a difficult problem understanding how profoundly rooted are problems of poverty and corruption. As a consequence, a good but limited idea was promoted as a broad and comprehensive solution.

In the end, the fate of the Amazon forest may critically depend on social policies and events that seem to many conservationists to be only marginally related to conservation. For example, subsequent to the creation of the extractive reserve programmes, the Brazilian government began to experiment with direct grant programmes for poor people. These programmes began with municipal sponsorship, then moved to the national level, and were expanded greatly under President Luis Inácio Lula da Silva (Lula), who took office on the first day of 2003. The programmes include access to a 'basic food basket', and 'family grants' that are given to low-income families who keep their children in school, send them for their required inoculations and health clinic visits, and meet

other basic criteria for responsible parenting. These programmes have made a significant difference to poor people throughout Brazil. To the surprise of many, it does not take a large portion of the national budget to add significantly to the income of a large group of desperately poor people, so the programmes can be maintained while sticking to budget criteria determined by the Lula administration's continued adherence to neo-liberal policies.

What is not well understood is how these programmes affect the dynamics of deforestation and the practice of sustainable livelihoods in the Amazon and other areas critical to biodiversity conservation. Do the grant programmes give families the margin they need for dignified survival and thus make it possible for them to refrain from activities that undermine conservation efforts? Or do they give poor people additional resources that allow them to become more aggressive settlers, less tied to the need to create sustainable livelihoods? Has it become more difficult, or at least more expensive, for timber firms and mines to attract people to dangerous and low-paying jobs? Will relative economic security reduce the corrosive effect of corruption and lawlessness, as many believe it will, or will the municipally administered programmes for the poor end up simply as a tool of corruption and control? At this point, we do not know the answers to these questions. In the end, it seems likely that the various support programmes for poor people may exert a larger influence over biodiversity conservation, for good or for ill, than the 'extractive reserve' programmes. National context may matter far more than 'on-the-ground' programmes that conservation organizations often design with insufficient attention to the influence of the context itself.

Similar issues arise throughout the tropics. In the tropical forests of Africa, conservation efforts are severely threatened by war and failed states. In much of Southeast Asia, forests continue to be devastated by companies operating under the sanction of very aggressive programmes of national economic growth within the forested nations and their main trading partners. In much of Mexico and Central America the coalition of local ranching land barons and national governments maintains a rapid pace of deforestation even when local people organize determined resistance movements. In every case, the pro-globalization, neo-liberal 'Washington Consensus' pushes relentlessly for the rapid and indiscriminating economic growth policies that help fuel these problems.⁶³

Conservationists cannot be expected to be able to control these problems. Nor can they be expected always to be able to minimize the effects of all of these problems simply through greater understanding – it is difficult to do much about some stubborn realities. In order to achieve long-term success in preserving biodiversity, however, they need to do two things: first, they should realize that they have little chance of success if they do not recognize the importance of understanding the local, regional, national and international context in which they work. Second, they can, so far as possible, ally themselves with the organizations and movements that are working for positive change.

Direct action land reform

During the time leading up to the assassination of Chico Mendes and in the years following, a well-organized movement for agrarian reform was making itself known throughout Brazil. The distribution of Brazil's vast and rich agricultural land originally took place amidst the violence and injustice inherent in colonial rule, but with particular aspects that created remarkably high levels of inequality, even among colonial regimes. The economy was driven by large plantations worked mostly by African slave labour. Land law was written by and for the plantation owners. The result was a society that was marked by enormous wealth for the few, and grinding poverty for the majority. Even after Brazil had become one of the world's largest industrial economies (varying between the eighth and twelfth largest during the latter part of the 20th century), with more than 70 per cent of its 185 million people living in cities, it remained among all countries one of the worst in terms of the gap between rich and poor.⁶⁴ Since the late 19th century, there had been one attempt after another to try to address the inequalities in the countryside (which in a variety of ways helped to recreate and maintain inequalities in the cities) through a land redistribution programme. None made much significant progress. A military coup in 1964 established a severely repressive government, in considerable measure to destroy increasingly powerful political movements demanding land reform. By the mid-1970s, the military regime was beginning to weaken and a new movement for land reform was slowly taking shape.

One of us (Wright) has written extensively about the *Movimento dos Trabalhadores Rurais Sem Terra* (MST) – The Movement of Landless Rural Workers. What follows is a summary of the movement as it relates primarily to biodiversity conservation.⁶⁵

The main method of the new land reform movement was to organize hundreds of land-hungry people to occupy land whose ownership could be effectively challenged. This was the Brazilian version of what has come to be known internationally as Direct Action Land Reform (DALR). Under Brazilian law, if land was not being used for productive purposes, the title to it could be challenged by a counter-claimant. This law was meant to encourage settlement and had come to be systematically manipulated by influential landowners in order to wrest land from the less powerful. In the US, similar provisions of law, such as water law in many states, are referred to by the phrase 'use it or lose it', or more formally, as 'effective use law'. Also, because Brazilian land law had become enormously complex, self-contradictory and corrupt, most nominally legal titles were subject to court challenge as fraudulent. In addition, considerable land was held by the states and federal government and was subject to claims of private appropriation in the name of putting it into productive use. By occupying land and mounting a legal case for ownership, the land-hungry rural poor were using the contradictions of Brazilian land law that had always served the interests of the rich in dispossessing the poor.

The land occupations were usually met by long campaigns of legal manipulation, intimidation and violence, carried out by a combination of police, military and private gunmen hired by wealthy landowners. In the late 1970s and later decades, however, the land reform movement was able to force the government to grant land to the occupiers, although often at great cost in lives and trouble. The amount of territory in land reform units by the end of 2005 was officially about 60 million hectares and was allotted to about 667,000 families. This accounted for more than 16 per cent of all Brazil's farmland. The process continues, with land reform advocates committed to gaining more land, and the government committed to an emphasis on making current land reform settlements viable through technical and financial support.⁶⁶ This development would come to have a variety of important implications for the future of Brazil's forests and other wildlands.

The Amazon played a major role in the drama of land reform, but not simply in the straightforward sense of being a source for land reform appropriations. One of the chief tactics of the national government to try to forestall the development of a new land reform movement was to offer land grants in the Amazon. In 1970, Brazil's President announced that in the Amazon, Brazil could provide 'a land without people for a people without land'. 'The land without people' being President Medici's quite inaccurate description of the Amazon. This was to serve the purpose of avoiding land redistribution in Brazil's established agricultural regions while providing labour for the ongoing development of the Amazon for economic purposes. The Amazon had a very negative image in the minds of Brazilians who had seen one settlement scheme after another fail in the face of harsh conditions in the region. Many of the poor who were there had been brought there under conditions of virtual slavery – this included many of the rubber-tappers who had been literally drafted into 'the rubber army' during World War II, received little or no compensation, and were left abandoned at the war's end. The Brazilian poor had often personally known families whose lives had been devastated by ill-advised attempts to settle in the Amazon, often succumbing to malaria and an array of other diseases endemic in the tropical forest. The poor were not clamouring to get to the Amazon. To the contrary, the military regime understood that it would have to attract them there by promises of land grants, schools, clinics, roads and housing. The government hoped to lure people to the Amazon with the promise of land, not only, and perhaps not mainly, to clear new agricultural land, but also to use these people as labour for road and hydroelectric dam building, timber extraction, mining and industrial enterprises, partly and precisely because agricultural settlement would in many cases fail. It was the military government's initiative in the Amazon that set off worldwide concern for the future of the world's largest tropical forest and, overwhelmingly, its most important reserve of biodiversity.

The government's programme to lure people to the Amazon posed a strong challenge to the land reform movement. The bitter historical

experience of Brazil's poor was that frontier development had always been disappointing. For centuries they had been induced to clear forests and scrubland because they lived in desperate poverty in developed agriculture areas and were offered the hope of something better, including the possibility of owning land in the new frontier. On the frontier, they were often able to make and defend claims to new land for a time, but were nearly always displaced as the more powerful land barons moved in. The vast majority of those who had invested their labour and faced danger and disease in opening the frontier would lose whatever land they had gained. They would become, once again, hopelessly indebted dependents of wealthy landowners. Virtually all of Brazil's once enormous area of Atlantic Coast rainforest was felled in this manner, where it had not been cleared earlier by slaves. According to some estimates, about 93 per cent of the Atlantic Coast rainforest has been cut. In spite of this experience, it had proven possible to lure the poor to repeat it again and again, driven by desperation and a shred of hope. The land reform movement wanted to avoid leading people into this trap again, and they rightly foresaw that this was what would happen in the Amazon.

The leadership of the land reform movement also believed that for viable communities to grow from land redistribution, it would be critical for people to remain in the regions where the soils, climate, culture, sympathetic public figures and neighbours were familiar to them. They also believed that the process of land reform would never be successful over the long term unless the political power of the rural oligarchies was successfully challenged. Land reform meant not only land redistribution but democratization of the countryside and of national politics. If people were continually lured into new frontiers none of this would happen – to the contrary, dispersed and unorganized families would be dependents of government colonization schemes and land barons rather than an organized political force in their own right. An authoritarian and reactionary regime of power would be extended over a larger territory. Following this logic, the land reform movement, and its most successful organized proponent, the MST, firmly rejected Amazon colonization and frontier development, consistent with their vision of what land reform was meant to accomplish, and consistent with the requirements of a viable organization.

In spite of this clear and consistent stand, conservationists tended to be wary of or hostile to the MST and other land reform organizations. They tended to see all small-scale agriculture in the same negative light. Often conservationists talked privately of the 'rapists and the ants' as the twin causes of deforestation, with the rapists being the large, well-financed landowners and corporations, and the ants being small-scale agriculturalists nibbling away furiously at the forest edge. Both were seen as the enemy, and only seldom was it remembered that if the ants were destroying the forest, they were encouraged or compelled to do so by the

rapists. In any case, the objectives of conservation were largely defined as protecting forest from everyone and from all forms of encroachment.

Conservationists, to the degree that they knew anything at all about Brazilian land law, also worried that the 'use it or lose it' provisions of the law provided a powerful incentive for conversion of all land into agriculture as a requirement of ownership. When they saw the land reform movement making use of this provision of Brazilian law, they saw the movement as an implacable enemy, even after the law was definitively changed in this regard, with the cooperation of the land reform movement. A narrow focus on conservation has often resulted in a failure to appreciate or even acknowledge those aspects of the land reform movement that put land reform on the side of conservation.

The first and most obvious thing that conservationists seemed oddly blind to was the fact that the major land reform organization was among the most prominent and militant opponents of wholesale development of the Amazon, for the reasons cited above. They missed that this was not simply an opportunistic public relations stance by the MST, but a deeply self-interested position taken on behalf of the organization and its members. From the 1970s through most of the 1990s, conservationists could not seem to see that if land were redistributed in already developed agricultural areas then the pressure on the Amazon would be eased by the reduction in the number of desperate rural people willing to take on the multiple challenges of life as Amazon settlers. Many still cannot see this. The majority of conservationists were taking for granted that the government's programmes for colonization of the Amazon were sincere but misguided attempts to provide land for the poor. Many Brazilian and foreign analysts were convincingly making the case that the government had little interest in the welfare of the poor, but rather was cynically manipulating them on behalf of Brazilian and international corporations interested in timber and mineral resources, and to protect what the Brazilian military saw as an imperative to settle the Amazon in the interests of national security.⁶⁷ Far too many conservationists for a long time failed to listen to this critique and made many mistakes as a consequence, wasting a lot of time trying to explain to the government the limitations of Amazon soils for agriculture. In fact, the government was far more knowledgeable and skilful at assessing the possibilities and limitations of Amazon soils than were conservationists, but had different objectives than the conservationists and than those the conservationists imagined were driving government policy.

By the early 1990s the land reform movement had to reassess its position with regard to the Amazon. They had not been very successful in slowing the pace of Amazon development, nor had anyone else. They also continued to struggle mightily with the problem of the legal impunity of influential landowners, a problem that undermined almost everything they accomplished. The Amazon frontier was a notoriously violent theatre

of conflict between poor settlers and richer ranchers and agribusiness operations. In the most violent regions of the Amazon – which were also the areas where the most rapid deforestation was occurring – poor people were desperate to create or join organizations that could defend them and represent their interests. Older 'rural union' organizations had established a presence in the Amazon, but they were largely ineffectual. Many settlers hoped that the much more aggressive MST would better represent their interests. The MST began to move into the region. They organized themselves aggressively in selected key areas where they quickly moved into conflict with the dominant rural power structure. In 1994, a march of MST members in the southern part of the state of Pará was attacked by local police and state-controlled military forces, resulting in the deaths of at least 19 MST members. The incident shocked urban Brazilians who had been largely unaware of the struggles going on in the Amazon. Many felt compelled to protest and, perhaps more importantly in the long run, to try to understand what was happening. This led to a period of wider sympathy with the land reform movement and to a deeper understanding of the dynamics of Amazon deforestation.

In the Amazon, the MST must deal with difficult contradictions. It represents settlers who often have little experience or knowledge of farming in a humid tropical environment. Many of the settlements are unlikely to be sustainable for long. The MST is proud of always aggressively defending the interests of its members, but is it to conclude that this means commitment to a moving frontier of settlement? Does this mean that the organization will be abandoning its rejection of Amazon settlement as a solution to the problem of Brazil's landless rural people? We do not know the answer to these questions yet.

The MST has not always been clear and consistent in meeting this challenge. Vague statements about sustainability and respect for conservation efforts sometimes contrast with much more militant statements and actions that simply defend MST members in disregard of conservation questions. This is sometimes true whether or not their farms and their claims on new land represent sustainable enterprises. Fortunately, however, there are also more positive and significant elements in MST policies.

A significant positive development in MST policy is the product of another kind of inexorable logic about responsible land reform. The MST began with a rather simple-minded approach to the question of what kind of agriculture served the interests of its members. They were inspired by three sources: first, the kind of highly capitalized, highly mechanized and chemical-dependent agriculture practised by those who were driving them off the land in Brazil, which they assumed had found the key to success since it was so successfully displacing them; second, the same kind of agriculture as seen in agricultural publications and taught to agronomists in Brazil; and third, the same kind of agriculture as seen in the US, Cuba and the Soviet Union (places some of the membership had visited and others had admired from afar). This agriculture was mostly devoted to

producing a limited range of basic commodity crops – maize, wheat, soy and sugar – sold in highly competitive international markets.

The MST soon ran into several problems attempting to implement this vision of agriculture on land granted through the reform programmes. The first was that farmed as individual units, the farms were too small to support the level of capital investment required. While some in the MST wanted to establish large collective or cooperative farms, most of these ventures did not succeed and most members wanted to farm their own individual holdings. The second problem was that it was very difficult to get credit – government credit programmes were insufficient and private creditors had little faith in the land reform and its beneficiaries, and in any case, charged very high interest rates. Third, when MST farmers did succeed in surmounting these obstacles, they began to see that chemical-dependent agriculture based on one or a few crops with little crop rotation and diversification created a whole range of difficult problems (as discussed in Chapter 3) that required more capital to deal with and in the long run threatened irreparable harm to the land. Unlike the larger, more heavily capitalized farms, they could not compensate by leaving large amounts of land in fallow, nor by buying land in new frontiers of agricultural settlement, nor by seizing the land of other less powerful farmers. The land they had received through the reform would be the land upon which they had to build their survival, and if it were damaged by unsustainable methods there was not likely to be a second chance. Land reform law prohibited multiple serial assignments of land to the same family and, besides, the effort required to gain a second grant was forbidding as a practical matter under most circumstances. Furthermore, they had little knowledge of, and no control over, the distant and volatile markets in which the major commodity crops had to be sold.

As this experience was accumulating, the MST also worked at getting advice from more progressive agricultural scientists and technicians in Brazil, and at building alliances with other groups in Brazil and abroad. Some of the more progressive people in agronomy were participating in a national and international dialogue and process of experimentation towards the creation of more sustainable forms of agriculture. Some conservation and social change groups they allied with were strongly committed to the cause of sustainable agriculture, and many were eager to offer advice and training. The MST began to come into contact with the growing and lively community of people practising alternative agriculture in Brazil. A new vision began to form.

The MST began to realize that they needed to practise techniques that preserved their hard-won land. They needed to minimize capital requirements, meaning that they needed to reduce reliance on chemical inputs; they needed to plant a diversity of crops; they needed to practise techniques to avoid damage to the soil and to control pests at minimum expense; and they needed to be able to sell in markets that were less volatile. They began to sell a diverse array of fruit and vegetable crops,

fish from aquaculture ponds, poultry, honey and herbs in local markets. This led to better appreciation of the advantages of capturing more profit by on-farm processing that added value to the product. They also made more profit from direct marketing in local farmers' markets. Participation in local farmers' markets brought them into more contact with neighbours and townspeople, improving the level of community understanding and support for what the MST was trying to achieve. Every aspect of this process was continually reinforced by people in many of the other groups with which the MST was allied, in Brazil and abroad.

By 2001 the MST was ready to announce that it was as an organization committed to practising 'agro-ecological farming', based on this new vision. Many members of the MST had little or no idea what this meant and others opposed the idea. However, there were many in the organization who had substantial traditional knowledge consistent with sustainable practice and had been putting that knowledge to work. Others were well ahead of the leadership in learning from the new local and international sustainable agriculture movement and from traditional practitioners in their regions. With some resisting and others out ahead of the central leadership, the MST has been unable to implement its vision consistently. It is, however, insistent on pushing forward with an agro-ecological ideal and with promoting and teaching the practice of it to its members. In addition, the MST has joined a coalition of environmental groups in consistently opposing the government's approval of genetic engineering in agriculture, where a convincing case has not been made for the value and safety of genetically engineered crops and livestock. The organization also insists that the question of ownership of intellectual property rights in genetically modified organisms has to be resolved in favour of equitable access and use. The MST has also opposed a variety of environmentally damaging programmes supported by the government, including large eucalyptus plantations for cellulose and bio-fuel production, diversion of the scarce water resources of the Sao Francisco region, various dam projects, and incursions on indigenous territories. The MST has been among the sharpest critics of the enormous expansion of sugar cultivation for the production of ethanol, as proposed by the Brazilian government and an alliance of agribusiness interests. It consistently opposed the expansion of the large-scale soybean farms that have been devastating the savannah region (the *cerrado*) and, increasingly, the humid forests of the Amazon. Although in most of these cases they were working in collaboration with environmental groups, in almost all of the cases it was the MST, and very few of the environmental organizations, which was willing to mount aggressive and persistence actions that might make some difference. MST members have put their lives on the line in blockades, sit-ins and other direct action with regard to important environmental issues over and over again, while in most cases environmentalists took little action beyond statements of protest and attempts to lobby politicians, putting little at risk. Still, some environmentalists are reluctant to give up

long-held prejudices that make them wary of land reform in general and the MST in particular.⁶⁸

In the Amazon, the MST, while jealously guarding its organizational independence, is eager to cooperate with environmental groups and conservationists. It tries to draw on the experience of those within the organization who have experience with sustainable agriculture in the Amazon. Many of these people are illiterate or semi-literate, so learning from them requires patience and close observation. Many MST settlers in the Amazon are anxious to minimize their impact on the neighbouring forest and are eager to find a way to do so while making a living. Fortunately, the MST has since its founding been based on the innovative educational ideas of Brazilian educator, Paulo Freire. Freire's methods encourage people to think in ways that are both relentlessly critical of existing realities and at the same time highly practical; they are ideally suited to the task of creating new kinds of livelihood when faced with new environmental contexts. One finds MST members in the Amazon practising a rich mixture of new and old techniques with an experimental attitude and a strong environmental consciousness (Figure 4.4). They represent an unusual opportunity for collaboration between farmers and conservationists.

At the level of national policy, the MST position remains sharply sceptical of plans to develop the Amazon and is opposed to continued deforestation in the Amazon and elsewhere in Brazil. However, it no longer attempts simply to stand in the way of Amazon settlement. Both



Figure 4.4 *Raimundo Pereira Galvão, a settler in an MST land reform community in southern Pará, Brazil*

Note: Pereira Galvão has planted 15 perennial tree and bush crops in order to achieve some of the agronomic advantages of a diverse mix of perennials in a rainforest environment. He also preserves a portion of his land in native rainforest, in accordance with Brazilian law.

Source: Angus Wright

the MST and conservation groups have come to realize that this cannot be done. What might be possible, however, is a set of new alliances between those fighting for social justice and those fighting for conservation: alliances that would go beyond the significant achievements of the rubber-tapper-conservationist alliance that led to the creation of the 'extractive reserves'.

Agrarian reform: a transcendent issue

In 133 BC, the Roman emperor Tiberius Sempronius Gracchus proposed the *Lex Sempronia Agraria* law, which would have provided land rights to landless peasants. During the final century of the Roman Empire, wars in far off places required long deployments of legionnaires, most of whom were farmers who left the farm with wife and children to defend the Empire. Frequently the understaffed farming unit would go broke and the land would be sold to another farmer, usually someone who already had a lot of land and worked the land with slaves rather than with his own hands. Returning legionnaires, now landless, filled the streets of Rome, creating the sort of urban crisis so familiar (unfortunately) to those of us in the modern world. Tiberius sought to rescue some of that land and redistribute it to these homeless families – the basis of the *Lex Sempronia Agraria*. His reward was murder at the hands of congressmen with strong interests in protecting the land rights of another group: those who already had the land.

Ever since (and certainly before), the issue of who 'owns' the land⁶⁹ and who is without title has been an issue that drives historical change. Agriculture is obviously dependent on access to land, and the socio-political arrangements that dictate agrarian laws are seemingly under continuous dispute. Those with land normally also have political, as well as economic, power, and the legitimate argument that their way of life, and consequently the way of life of the country, nation or state, is dependent on their owning large tracts of land. Those with no land have a much more direct argument: that they cannot feed themselves and their families without land, but frequently lack the economic and political power to confront those with the power. When the landless organize themselves into socio-political groups to exercise the obvious political power that emerges from group action, political power emerges. The political power of the landed rich then confronts the political power of the landless multitude – and sometimes agrarian laws are changed.

This process happens the world over, and has been a key element in political change. But the modern form, especially evident in Latin America, is what has sometimes been referred to as DALR, in which the landless simply occupy land that is under-utilized by a large landowner. Armed with complicated legal structures that frequently enshrine the right to land only if it is utilized, such direct action basically challenges the state to intervene, as in the case of the MST as discussed in the previous section.

The most common pattern is when an organized group of landless farmers occupies a piece of land that is evidently not being used for productive activities – frequently land that is being held for speculative rather than productive purposes. Governmental authorities are then challenged to adjudicate proper tenure. The arguments can become complex and politically loaded, but basically boil down to two contending ideas about who is the true owner: the landless family whose claim is the historical right to land, or the current owner, whose authority usually rests in a contentious claim that his or her ancestors somehow ‘claimed’ the land. Given the underlying construction of the problem, it is not surprising that such land takeovers are frequently referred to (by the landless engaged in the takeover) as land ‘rescues’, and why ‘redistribution’ is a word frequently employed.

From the perspective of this book, there is an obvious point that merits consideration: that ‘under-utilized’ land may very well be an old-growth forest or pristine savannah that contains huge amounts of biodiversity. The agrarian laws governing such land rescues have, in recent years, been significantly modified so as to avoid the claim that a biological reserve (say) is actually under-utilized, and most DALR efforts are in fact aimed at large, mostly absentee landowners who produce little, maintaining much of their land for speculative purposes. The matrix to which we have repeatedly referred in previous chapters is often the target of groups seeking land reform. It would seem obvious that our argument for a high-quality matrix as key to biodiversity conservation includes an argument to take into account the activities of the landless who are determined to be landed.

THE DEPENDENCY TRAP IN BIODIVERSITY CONSERVATION

The essence of living and working within ex-colonies, with ‘dependent’ economies, is that one’s livelihood is strongly affected by decisions and events that are taken elsewhere and that are unusually difficult to control. In one sense this is clearly a matter of degree because nearly everyone’s livelihood is affected to some extent by things that are remote and hard to influence. However, the degree to which it is true is absolutely critical to people’s lives, and is dependent on particular kinds of relationships among national economies. A freeze in Brazil can result in higher coffee prices in New York or London, which may result in inconveniences for cash-strapped and caffeine-starved students and office workers. In contrast, if the price of coffee falls significantly on international markets, it is not simply a matter of inconvenience for those in coffee-producing regions and nations. A fall in coffee prices may result in tens of thousands of farm workers being laid off or tens of thousands of small-scale farmers losing their livelihoods in a producer nation. Thus, low commodity

prices have often resulted in generalized hunger and mass migration. Sometimes landowners are unable to pay off loans and therefore lose their land. Local people engaged in all the activities that depend on the coffee economy suffer as well. In most coffee-producing nations, economies are not highly diverse and domestic markets are relatively weak, so changes in commodity prices ramify strongly through the entire economy and political system. Brazil used to fit this description, but industrialization, a more diverse agriculture and a better-developed local labour force and internal markets have greatly reduced the problem. Most of the coffee-producing countries of Central America and Africa still suffer drastically from coffee price fluctuations. Frequently, such price declines are quickly reflected in severe political crises as governments plunge into dramatic debt and are unable to protect citizens from the cascade of events that ensue.

The history of most tropical and subtropical countries can, to a large extent, be written in rough form as a reflection of the rise and fall of basic export commodity prices. Such crises can have dramatic effects on the survival of natural areas and biodiversity, sometimes leading to expansion of agriculture to compensate for low commodity prices, sometimes leading to timber cutting and other forms of raw resource extraction as the most readily available source of income when there is little money for capital investment. In some prolonged falls in commodity prices, there may be a benefit to biodiversity, as land is abandoned and allowed to return to natural vegetation. But more often, such abandoned agricultural land is turned over to extensive uses, such as ranching, with little if any gain for biodiversity, and often a loss.⁷⁰

The world's developed economies are more buffered against these fluctuations in export commodity prices. First, they are highly diversified. Declines or disruptions in one part of the economy are usually cushioned by relatively normal conditions in other sectors.⁷¹ Export dependence tends to be relatively low – most people engaged in making, buying or selling goods and services are dealing with people within their own nation. Purchasing power is spread relatively broadly among the population so that there is a large and resilient domestic market. Political institutions are able to reduce the stress on people and firms in economic sectors that are suffering – most famously through commodity price support programmes in such areas as wheat, maize and cotton agriculture. And governments have many other ways of taking the heat off distressed economic sectors. They create and maintain broad social safety net schemes, such as unemployment insurance and social security. Most financiers and corporate heads have at least some interest in and awareness of the need for maintaining the economic health of the majority of the population in order to provide a strong domestic market. They also see the importance of basic social services such as health and education that provide skilled and healthy workers. That this basic structure and set of perspectives in richer nations has been considerably shredded in recent decades clearly

modifies this picture. But relative to most poorer nations, the contrasts still remain strong, if not stark.

The strength of the richer nations with respect to the poorer has been a fundamental fact of international relations for several centuries. Beginning in the colonial era and continuing to the present, richer kingdoms and, later, nations have been able to build diplomatic, military, trade, financial and even cultural relationships that maintain and often reinforce the differences between rich and poor 'countries'. These relationships have been so meticulously built and defended for so long that they constitute a rather rigid structure of international power. Many are so ingrained that most people in richer nations tend to take them for granted and do not tend to question their purpose or actions. They are more obviously troublesome to those in poorer nations who suffer from them. Indeed, one way to write much of the history of poorer countries is through the stories of leaders and political movements that have from time to time attempted to effect positive change in their own countries by negotiating better deals within the structure of international power, by trying to reform the structure, by trying to become more independent of it, and/or by direct diplomatic or military confrontation with it.

As discussed above, the neo-liberal model (also known as the 'Washington Consensus'), which has been so influential in shaping international relations since the end of the Cold War in the early 1990s, relied on persuading or pressuring poorer countries to accept a set of international agreements and policies that largely had the result of strongly reinforcing the older structure of power. The basic argument of this neo-liberal focus is that 'a rising tide lifts all boats' – that is, that more economic activity results in better lives for rich and poor alike. The way to promote a rising tide in this view is by reducing barriers to trade, lowering taxes and lowering government expenditures on social services, and lightening the burden of regulatory measures on business. Freed to invest, buy and sell as they like, businesses will be able ultimately to produce more goods and services, and employ more people. Those who reject this argument, and we are among them, argue that such an approach at best maintains the inequality built into the old international relationships, and at worst, makes these inequalities much worse. When the neo-liberal model has its way, in the best of circumstances, the rich get richer and the poor get somewhat better off. In most circumstances, the poor are helped very little or are harmed. In virtually all circumstances, the international structure of unequal power is strengthened and thus dependent economies become more dependent than ever.

One of the most powerful effects of the structures of international economic relationships, even before neo-liberal dominance, is that poorer countries are chronically deprived of capital investment for economic growth. Apparently the easiest solution to this problem is an unhealthy emphasis on raw commodity production – including timber and minerals – and cheaply produced agricultural products that require relatively little

capital investment. Production of such commodities means that natural habitats and biodiversity pay a disproportionately high price. Furthermore, because of the relative vulnerability of dependent economies to economic slowdowns, cycles of severe debt are characteristic. Debt creates yet stronger incentives to rely on production of commodities that require little new capital investment, and once again, biodiversity suffers as a direct consequence of economic dependency.

It is essential to understand the importance of these issues when considering how to protect and prevent losses of biodiversity in the tropics. The situation of economic dependency is one that affects most of the countries that shelter most of the world's biodiversity. This creates several major problems. The first is obvious: most such nations are poor and are not inclined to favour conservation over opportunities for increasing economic activity. This aspect of the situation is understood by nearly everyone involved in the controversies over biodiversity protection. However, some are more responsive than others to the concerns it raises. Some are aware of the problem yet find it so overwhelming that they are forced into a posture of ignoring it. Some simply declare biodiversity to be so important that it cannot be allowed to play second fiddle to human welfare. In any case, the nature of this argument has long been clear and we can shed little new light on it here. We do take it as a given that no discussion of biodiversity protection that seeks to gain enthusiasm and consent within the biologically richest nations, most of them economically poorer nations, can long ignore the need for substantial improvement in human welfare. Conservation plans need to be at least compatible with measures taken to improve peoples' lives. Ideally, they should make a positive contribution to both conservation and human well-being. There are relatively few in the conservation community who openly disagree with this point of view.

A second and not quite so obvious problem created by structures of economic dependency is that many plans, projects and schemes put forward by conservationists may fall disastrously into what some analysts have called 'the dependency trap'. Worse, in many cases conservationists may inadvertently be making the problems of economic dependency more severe than before they entered the scene, with plans and projects that recreate and reinforce the structures of dependency and poverty that are the chief threats to natural habitats and the biodiversity contained within.⁷²

The most obvious form of dependency for conservation projects in nations of the Global South is the straightforward need for continual financing from other national governments, international organizations and individuals. The national governments of tropical countries are often unable or unwilling to provide reliable financing and many have come to rely on outside funding for particular conservation efforts. This is often the case even when protected areas are designated as national parks or reserves, and administered by national governments: continual

active administration and enforcement sometimes depends on continued external sources of money. When a funding cycle by, say, the UN, USAID or the WWF comes to an end, the question may remain whether any new funds will be forthcoming. When they are not, or when they are reduced, the whole conservation project can languish or fail altogether.

Other forms of dependency can be built into plans to provide an ongoing local economic foundation for conservation projects. For example, some conservation projects rely heavily on tourism as a way of harmonizing conservation and economic development. To be compatible with conservation goals, tourism must be kept within strict rules and boundaries. Eco-tourism of this type appeals only to a certain fraction of the tourist trade, while the majority of tourists would favour, say, a large new resort hotel with all the conveniences over a modest thatched building that is more compatible with conservation. Consequently, investors are generally more attracted to conventional than to genuinely conservation-based tourism. The experience of the last decades clearly shows that there is a healthy market for authentic eco-tourism that lives within the limits of what the environment can bear, but it is a distinctly small portion of the total tourist trade.

The kind of tourism that is based on luring visitors to healthy local ecosystems in the tropics is, sadly, another tropical luxury commodity, in the sense that – like coffee, tea, bananas and sugar – it is subject to strong demand elasticity. Relatively minor downturns in richer countries can have disastrous effects on eco-tourism, as it can on international tourism more generally. This problem is becoming more acute as there has been a rapid proliferation of eco-tourism opportunities competing for the international tourist's dollar.

In addition, most of the people who are enlisted to work in the eco-tourism industry have relatively low skills. In many instances, people with substantial and valuable local knowledge in farming and forest survival skills become baggage handlers, drivers, maids and cooks. Some become guides who are given scripts to follow. Most guides are not recruited from the rural people living in and around the forest or other natural habitat, but rather are recruited among urban high school and college graduates, as with most of the relatively well-paid jobs. For the majority, the seasonal and vulnerable nature of the employment provides relatively low income, few opportunities for real advancement and high levels of insecurity.

To make matters worse, many conservation schemes rely on the physical dispossession of people living in and around the conserved ecosystems. Such people are literally displaced persons who are forbidden to use the local landscape in the ways they once did. This problem is acute in many of the East African wildlife parks, for instance, where widespread dispossession left whole peoples in a state of perpetual poverty.⁷³ In some of the more notorious cases, the best agricultural land went to white settlers during the colonial years, and more recently, to successful national politicians. And the best land remaining for hunting and grazing was

converted to wildlife reserves. While not all wildlife reserves in East Africa have been so brutal to local people, many have, and it has made even the most conscientious conservationists much less welcome than they might otherwise have been. It is no wonder that, as a desperate means of survival, locals either turn a blind eye to wildlife poachers, or actively engage in poaching or supportive activities. Disreputable merchants, armed gangs and corrupt politicians often find little resistance to the ruthless picking clean of the carcass of poorly designed conservation plans, as in Kenya during the 1990s, when prominent political leaders working through large international smuggling rings were found to be profiting handsomely from large-scale poaching in wildlife parks. Of course, wherever this kind of situation has prevailed, it has tended to undercut the primary purpose of wildlife reserves, that is, to conserve wildlife. The charge is frequently made that those who promote compatibility of viable local economies with biodiversity conservation are blunting the desperate need for tough conservation measures because of an overly sentimental reaction to human distress. This charge is fatally flawed on two grounds. It is both morally bankrupt and contradictory to the conservation cause itself.

Many volumes have been written on this subject, and we do not intend to rake over the same issues again.⁷⁴ The key here is the urgent need to find ways to further biodiversity conservation without simply reproducing the situations of economic dependency that place both people and Nature in danger. It is a general and most obvious principle that natural areas will be successfully protected over the long run only when they are embedded within local, regional and national economies that provide for greater levels of economic diversity, resilience, security and political participation. An essential tool for moving in that direction is the integration of productive agriculture with conservation, which is the fundamental argument of this book.

The integration of productive agriculture with conservation cannot be accomplished, however, without strict attention to the legal and administrative framework and the macro-economic policies that must be in place to protect the larger purpose. For example, in Brazil, the national government has placed enormous forested areas under various kinds of legal protection. In sum, the protected areas amount to an area of land roughly equal in size to Western Europe. The amount of land designated for conservation, dwarfs what richer nations of the North have ever put into protected areas. The problem is that much of this land amounts to what is commonly termed 'paper parks', that is, theoretical legal protection in a social and economic context that makes such legalities meaningless.⁷⁵

For five centuries, Brazilian rural life has been dominated to a large extent by oligarchies of powerful families and firms who have shaped, twisted, bent and mutilated the legal system to their benefit. They have relied on the use of police and the military for the purpose of furthering their private gain, and when this has not been sufficient, they have turned to private gunmen and gangs. The regions where the forest is being cut

and burned in Brazil continue to be regions of frequent, endemic violence. Brazilian land law as it is actually practised and enforced is a quagmire of contradictions that provides not only opportunities but incentives for ruthless exploitation by timber and mining companies, ranchers and large agribusiness firms. Furthermore, the chronic poverty and desperation of the majority of the rural population guarantees relentless deforestation by those with few alternatives than either to work for exploitive resource-extraction corporations or to cut down forest to plant crops for minimal food and income. The systemic inequalities and violence built into regions undergoing deforestation is also fertile ground for widespread corruption. The legally protected areas cannot reliably withstand the brutally destructive and corrosive context that surrounds and contains them.⁷⁶

Mexico provides a somewhat different example. In some of the biologically richest areas of Mexico, villagers have done their best, under very difficult circumstances, to preserve forests and forest remnants over which they have exercised some degree of legal and/or customary control. They have struggled with many problems over centuries that have made it difficult to preserve forests, and often they have failed. But in spite of all the failures, there has been a degree of success – enough so that Mexico, virtually no inch of which has not seen some kind of human habitation and use over several millennia, has retained an unusual wealth of species diversity. Since the 1980s, however, and at an accelerating rate, the protection that villagers often exerted over forests has come under attack in several mutually reinforcing ways.⁷⁷

Since the early 1980s, the Mexican government, partly due to its own internal problems and decisions, and partly in response to international pressures, began to reduce the already minimal amount of financial credit and other forms of support it offered to small-scale farmers and land reform communities. This deepened an already existing crisis for the majority of Mexico's farmers. More than 50 per cent of Mexico's agricultural land was held by *ejidos*, a form of landholding that had been created by the 1917 Mexican Constitution, written toward the end of the country's major social revolution of 1910–1920. The *ejido* was loosely modelled on ancient village forms of landholding that had prevailed in Mexico and Spain until the nearly complete concentration of land in the hands of large private landholders and the Catholic Church largely destroyed such forms. Under the terms of Article 27 of the 1917 Constitution, *ejido* land was owned by the state, controlled by a council of those who lived and worked it, and farmed, in most instances, by individual families. Various kinds of cooperatives, marketing co-ops and machine co-ops, for example, and work sharing among families were part of *ejido* life. Most *ejidos* had some amount of land that was treated as common land, including pasture and forest, and administered by the *ejido* council. The whole enterprise was almost totally dependent on government credit, because it was illegal to sell or mortgage *ejido* land. As government credit dried up, *ejiditarios* became desperate and many began to want to put an end to the legal

restrictions that made it impossible for them to access most of the private credit market.

At the same time, the US government and the institutions it heavily influenced, including the World Bank, the Inter-American Development Bank and the IMF, were pressuring governments all over the world to privatize state enterprises of all kinds, including state-owned rural credit banks. Private banks were eager to eliminate or take over such state financial institutions. Also, as part of the same international economic policy initiative, the US government was working hard to create a North American free trade zone, which would become known as the North American Free Trade Agreement (NAFTA). One of the key obstacles to NAFTA, from the point of view of multinational corporations and many officials in the US government, was the array of nationalist provisions in Mexican law, among which were the restrictions on land sales and mortgages that restricted the ability of companies to gain access to and own Mexican land and resources. These corporations, with the support of the US government, saw the elimination of such controls on land and resource sales as an important element in making a free trade area desirable and workable. In 1992, the Mexican government passed a Constitutional Amendment to Article 27 of the 1917 Constitution, making it possible for *ejiditarios* and other land reform beneficiaries to mortgage and sell land and such land-based resources as timber and minerals, without the kinds of restrictions that had applied previously. This paved the way for final negotiation of NAFTA itself, which came into effect in 1994.

The most important trade effect of NAFTA on rural Mexico was the elimination of the 50 per cent tariff on US and Canadian maize imported into Mexico. The agreement was founded on the promise of the US that it would eliminate virtually all price support payments and other subsidies to US farmers. However, after NAFTA came into effect, the US Congress proceeded to pass huge subsidy bills that meant that US grain farmers received an average of 40 to 50 per cent of all their income from government subsidy payments, while Mexican farmers were deprived of all significant subsidy payments. Along with the superb soils of the US Midwest and the very heavy capital investments made over decades in US grain farms, these events have resulted in a flood of cheap grain entering Mexico, severely undercutting Mexican farmers' already fragile economic viability. The result has been an ever more rapidly accelerating exodus from the Mexican countryside. It has also meant that those who do remain at home are frequently forced to sell their forests and minerals, if not the land itself, to companies that have rushed in to buy up everything of significant value. The negative consequences for forests and biodiversity are evident. There is probably some relief to native habitat and biodiversity in Mexico due to the reduction of the pressure of rural populations on local resources. However, in region after region of Mexico where villages are being virtually or entirely abandoned, a counter-effect is almost certainly more important for the future of the forests and biodiversity. When

villagers attempt to defend rather than sell off their resources, the task has been made extremely difficult. The defence of Mexican forests in village hands has never been simply a legal matter. In hundreds of cases it has been necessary for villagers to defend their land and forests through determined organization, mobilization and, often, resistance to physical violence perpetrated by local, national and international timber, mineral and land companies. Since the signing of NAFTA, there has been a sharp increase in the number of beatings, illegal incarceration and murder of villagers trying to protect their forests from exploiters. One of the best-known incidents involved the machine-gunning of 17 villagers crowded into a truck on their way to a meeting to protest against encroachments by a US timber firm. The incident is particularly well-known because it was captured in all its brutality on video tape.⁷⁸ The most prominent lawyer working for communities in the state of Guerrero trying to defend forest resources was assassinated in her Mexico City office.⁷⁹ The future of Mexico's native habitats and biodiversity will almost certainly be more critically affected in a negative way by such pressures and events than it is affected positively by the creation of additional parks and reserves. At best, the programmes to create and protect reserves will be seriously compromised by the larger problems of rural Mexico and its villagers. Villagers who are now working in Mexico City, Tijuana, Los Angeles or New York City can do little to help defend the forests and resources that their ancestors protected for centuries. Similar stories can be told in country after country.

What becomes increasingly evident is that biodiversity protection has long depended to a considerable degree on mostly poor farmers in relatively remote areas. While these same farmers have also often abused soils and forests badly, in the end, their physical presence in the areas and their self-interest in the protection of forests and watersheds have frequently made them a largely unrecognized force for conservation. Their many failings and shortcomings in this regard should not be used to condemn them, but rather to call attention to the critical need to support them. Particularly, conservationists should be active in seeking support for farmers who are ready and able to promote conservation goals. Such support cannot, in turn, be expected to be successful when national and international macro-economic and political forces make their very existence as rural people untenable. Nor is it justifiable for conservation policies, projects and strategies either to ignore the role such farmers can play in conservation or, worse, to promote or cooperate with economic policies that eliminate or weaken these farmers.⁸⁰

GRASS ROOTS SOCIAL MOVEMENTS

Resistance to the global system has been widespread, from Geronimo and before. Electing a government in Guatemala (in 1954) that promised to

provide land to landless peasants was not an accident, but the product of grass roots initiatives by farmers and labour unions. And the liberation struggles of the Vietnamese, the Nicaraguans, the Kenyans, the Chinese and the Indians, were all the product of grass roots social movements converging to form major political transformations in their respective countries (to say nothing of the US and France somewhat earlier). It is thus not surprising that we see the same thing today. It seems that the idea of democracy and justice are deep cultural rules that transcend the particularities of political and economic systems. Wherever there are oppressed peoples, there are grass roots struggles to end that oppression.

Yet today these movements have become more important than ever. The crisis of neo-liberalism may be very similar to the previous crisis of the old capitalist system (reflected in the Great Depression), but the solution, Keynesianism,⁸¹ is no longer available to us, largely because of ecological fundamentals – biodiversity will continue to be eroded and global warming may make the civilization that we know and live in unfeasible. Consequently, the solution to the previous crises of capitalism may not be available to us today. While a complete analysis of this possibility is beyond the scope of this book, we insist that any rational solution to the global crisis created by capitalism and neo-liberalism will have to take into account the environmental background, which suggests an examination not only of neo-liberalism but of the capitalist system itself. If Keynesianism cannot be a solution, what are we left with? We do not have an answer to that question, but we are convinced that the transformation of the agricultural system in dramatic and radical ways will be an essential part of the answer. And in order to effect that transformation, the participation of the current and potential future rural sector will be essential. The good news is that the pathway to that future seems to be unfolding through myriad rural social movements right now. From the point of view of this book, the connection between those social movements and conservation is essential.

Much as traditional agriculturalists have given tremendous insights into the development of agro-ecological principles, there has been a recent, if under-reported, surge of interest on the part of small farmers in the tropics in biodiversity conservation.⁸² Indeed, our experience is that small farmers in the tropics are frequently surprised to hear that some conservationists regard them as the enemies of conservation and the main cause of tropical deforestation. Although there is no doubt that landless peasants are partially responsible for the expansion of the agricultural frontier in areas like the Amazon⁸³ and the tropical rainforests of Central America,⁸⁴ blaming them for tropical deforestation is an oversimplification that ignores the political economy of agricultural development in tropical countries.⁸⁵ We elaborated on this issue in our previous book, *Breakfast of Biodiversity: The Political Economy of Deforestation*.⁸⁶ Decades of environmentally destructive mega-projects, such as the colonization of the Amazon in Brazil, transmigration projects in Indonesia, and the

establishment and expansion of banana plantations in Costa Rica and Ecuador, along with an uneven distribution of land, have been the principal causes of tropical deforestation.⁸⁷ Government policies that benefited a landed minority, owners of large rural estates, and in many cases foreign corporations, displaced small farmers from the best agricultural lands, effectively giving them two options: to move to the cities, or to migrate to the agricultural frontier.⁸⁸ However, in many developing countries the small farmers and the landless are organizing and demanding access to land and their right to a decent livelihood. These farmers' organizations, increasingly organized under the banner of food sovereignty, sustainable agriculture and biodiversity conservation, are an integral component of the discourse. Organized groups such as *Via Campesina*, a coalition of over 100 small-farmer and peasant organizations from around the world, are not only actively opposing neo-liberal policies (particularly the inclusion of agriculture in free trade agreements), but are now taking an active role in planning conservation activities and developing alternative agriculture.⁸⁹ Four of the ten key points of the *Via Campesina* platform are related to conservation and the environment. Brazil's MST, the largest rural social movement in the world, actively encourages and teaches agro-ecology, which includes protection of biodiversity and the development of sustainable agricultural principles.⁹⁰ At the 2003 meeting of the Mesoamerican Society for Biology and Conservation, Wilson Campos, a leader of *Via Campesina* in Costa Rica, spoke of the acknowledged responsibility of small farmers to conserve the environment, and specifically, biodiversity, for future generations. In the autonomous territories of the Zapatistas, an indigenous movement in Chiapas, Mexico, that has created its own autonomous form of government called *Junta de Buen Gobierno* (Board of Good Government), the word 'agro-ecology' has been appropriated by the communities, and agro-ecological projects are seen as part and parcel of community development (Figure 4.5a). Furthermore, their educational system places Nature and History at its the core, as prerequisites for all other disciplines (Figure 4.5b).

In conjunction, all these movements and their initiatives represent not only an alternative pathway toward development but a dramatically different concept of sustainable development from that promoted by the neo-liberal model and its supporting institutions. In sum, it is a conceptualization that emerges from the grass roots, and as such, has social and environmental equity as a central principle, and grass roots democracy as its methodological instrument. Although these so-called 'alterworlds' are in no way homogeneous, most of them have strong environmental ethics, and given that they are integrated by mostly small-scale farmers, peasants and landless workers from the Global South, they should be integral to the efforts to conserve biodiversity.



(a)



(b)



(c)



(d)

Figure 4.5 Zapatista farmers and students engaged in agro-ecological practices and learning: (a) young Zapatista students learning about the process of seed germination; (b) Zapatista farmers planting neem seeds (an infusion from the neem leaves is used as a natural insecticide); (c) Zapatista farmers preparing terraces for soil conservation; (d) a mural painted in a Zapatista school in Oventic, which states 'our philosophy is human beings as part of nature'

Source: (a–c) Schools for Chiapas; (d) John Vandermeer

Conservationists working with social movements

Realizing the need to work hand in hand with the small farmers who manage the agricultural landscapes in the tropics, some environmental NGOs are beginning to pioneer conservation programmes in collaboration with these progressive social movements. An excellent example of the kind of work that incorporates social justice and conservation in a highly fragmented tropical landscape is the work that the Institute of Ecological Research (*Instituto de Pesquisas Ecológicas*, IPE) is doing in the region of the Atlantic forest in Brazil.⁹¹ In the Pontal do Paranapanema, a large fragment and several smaller fragments of the Atlantic Coast rainforest form the Morro del Diablo reserve, surrounded by large cattle pastures with mainly absentee landlords, as well as settlements of small farmers established long ago by landless people, which are currently highly productive. These

small farms are the result of a DALR programme that began in the 1950s with rural unions, was largely abandoned during the repressive phase of the military government in 1964, and was renewed in the late 1970s with the support of Liberation Theology Catholic priests and the organizations that would become the MST. Using the basic ideas of DALR, families of landless rural workers occupied (rescued) pieces of unused land, mainly located on the huge and highly unproductive cattle ranches. After intense legal battles (and some less-than-legal armed conflict with the ranchers), many of those participating in land rescues were given legal titles. And what we now see is the result of a 40-year experiment with this sort of agrarian reform.

A visit to these small farms today reveals a remarkable success story. These families have a dignified livelihood with what could be considered by most a middle-class economic standard of living. In a country like Brazil, with one of the highest levels of inequality in the world, this is quite an achievement. But more importantly for our argument, the farms themselves are complex agroforestry gardens that seem almost a perfect example of what we expect a high-quality matrix to be (Figure 4.6). Indeed, a recent study of birds notes that biodiversity in these gardens is almost what it is in local patches of forest. For feeding, some of the birds even prefer the agroforests over the natural forests.⁹²

While the imposition of a military dictatorship in 1964 effectively ended the DALR operations throughout Brazil, the end of that dictatorship in 1984 saw a resurgence of those activities, and yet more unproductive cattle pastures have seen land takeovers by landless people, some organized by the MST. Rather than seeing the MST as their enemy, IPE began collaborating with the MST to diversify and increase the tree cover on the farms in the settlements, as well as to improve the livelihoods of the families involved. Initiatives like this will, in our view, contribute to the creation of an agricultural matrix that is socially just, politically stable and that will conserve biodiversity at the landscape level and in the long run.

It is important to note that what we are proposing here is qualitatively different from the Integrated Conservation and Development Programmes (ICDP) that attracted so much investment by bilateral development agencies and the Global Environmental Facility (GEF) during the 1990s, and that generated debate in development conservation literature.⁹³ Although these programmes began by addressing the need to look beyond reserve boundaries and pay attention to the welfare of the local communities, they retained institutional top-down approaches and stopped short of recognizing the pivotal role of rural social movements as protagonists of the new conservation. But more importantly for our argument, the ecological processes involving extinction in the fragments and migration through the agricultural matrix (as explained in Chapter 2) were not fully appreciated. It does not matter how much the ICDP programmes may have met their short-term goals if the underlying ecology, especially the quality of the matrix, was not taken into account.



Figure 4.6 *One of the agroforestry systems used by settlers in the Pontal do Paranapanema, São Paulo, Brazil*

Note: The picture shows Jefferson Lima, from IPE, and one of the settled farmers. Jefferson works closely with farmers in developing agroforestry systems to help maintain biodiversity in a region that is dominated by treeless and degraded cattle pastures.

Source: John Vandermeer

Social movements versus the traditional conservationist agenda

Conservationists in the past have focused on the purchase and protection of large tracts of land to be set aside as nature preserves, with surrounding areas acting as buffers. From what we now know about how biodiversity is structured ecologically, this is a doomed strategy if pursued in isolation, as we explained in detail in Chapter 2. A review of the implications for biodiversity protection of Amazon and African protected areas by scientists at Duke University (US) recently concluded, 'Size matters, and so, too, must the matrix.'⁹⁴ While there is no rational need to convert any more forests to agriculture, they are in fact being converted, and the future will almost certainly present us with mainly fragmented landscapes. It is in these fragmented landscapes that most of the world's biodiversity will be located. A long-term plan for biodiversity conservation needs to

acknowledge this fact and work at the landscape level, not only to focus on preservation of the patches of native vegetation that remain, but also to construct a landscape that is 'migration-friendly'. Such a landscape is most likely to emerge from the application of agro-ecological principles. And these principles are most likely to be enacted by small farmers with land titles – a product of grass roots social movements.⁹⁵

Social movements will also be needed to change the overall conditions that determine the budget priorities and policies of governments, and the relationship of governments to banks and corporations. While agrarian reform movements are only a small part of the larger set of political initiatives that will have to be taken to achieve a more just and sustainable world, they are a necessary part and one that is particularly close to the problem of biodiversity conservation. The union of conservation with social justice in the countryside is one starting point for the wider union that will be necessary to protect habitats and species. While emphasizing that 'Most of the political and economic constraints on the sustainable use of natural resources by people in a rural locality originate elsewhere ... [and] can seldom be removed through local initiatives alone', Barraclough and Ghimire conclude, in a study sponsored by the UN and the WWF that:

Without the mobilization and organization of peasants and other low-income residents with the aim of gaining greater control over resources and institutions, however, there seems little likelihood that wider sub-national, national, and international political systems will seriously take their interests into account when formulating and executing policies affecting them. Local-level initiatives aimed at approaching more sustainable development through community-based resource management necessarily imply a struggle for greater control over resources and institutions in specific social contexts by those hitherto excluded from such control. Such struggles for self-empowerment are inevitably highly conflictive.⁹⁶

We see a dichotomy of positions, with one side purchasing land in pristine areas to be protected by armed guards, and the other side marching with the poor in their struggle for revolutionary change. Naturally this is something of a caricature, but it does capture the two poles of thought that we encounter when we read and talk with people concerned with biodiversity conservation in the tropics. Beyond caricature, the two positions urgently need to be reconciled in order to achieve effective species protection, linked, as it must be, to improved human welfare.

If the phenomenal rise in rural grass roots social movements continues, it is here that the future of rural landscapes will be determined. Since it is the agriculture in the matrix that is key to the overall conservation agenda, as we have argued, the social movements that form the basis for the future organization of that agriculture become key players in the overall conservation agenda. The *Via Campesina*, with its philosophy of food

sovereignty, agro-ecology and conservation of natural resources, offers an excellent example of where conservation energy should be placed at the present time.

NOTES

- 1 Funes et al (2002); Wright (2008).
- 2 McNeill (1977); Hughes (2001); Richards (2003).
- 3 Anderson and Grove (1987); Neumann (1998); Adams and McShane (1997); Hardin (forthcoming).
- 4 Franke and Chasin (1980).
- 5 Anderson and Grove (1987); Neumann (1998); Adams and McShane (1997); Brockington et al (2008); Hardin (forthcoming).
- 6 Tucker (2000).
- 7 Hughes (2001); Richards (2003).
- 8 Guha and Martinez-Alier (1997).
- 9 Rojas Rabiela (1983, 1994); Mann (2005); Wright (2005, chapters 5–8); Miller (2007); Heckenberger et al (2008).
- 10 Rojas Rabiela (1983).
- 11 Pyne (1982); Williams (1994).
- 12 Mann (2005); Heckenberger et al (2008).
- 13 McNeill (1977); Hughes (2001).
- 14 Wright (2005).
- 15 Melville (1994); Richards (2003); Wright (2005); Miller (2007).
- 16 Keay (1991); Prakash (1998).
- 17 Tucker (2000); Wallerstein (2004); Speth (2009).
- 18 Melville (1994); Miller (2007).
- 19 Sauer (1955).
- 20 McNeill (1977); Hughes (2001); Richards (2003).
- 21 McNeill (1977); Tucker (2000); Hughes (2001); Richards (2003).
- 22 Guha and Martinez-Alier (1997, chapter 8).
- 23 Revkin (2004).
- 24 Maathai (2006).
- 25 Collier (2005).
- 26 Rich (1994); Stiglitz (2003, 2005).
- 27 Escobar (1995).
- 28 Stiglitz (2005, 2007).
- 29 Rich (1994); Stiglitz (2003, 2005).
- 30 Rich (1994); Stiglitz (2005).
- 31 Johnson (2004).
- 32 Stiglitz (2003, 2007); Harvey (2005).
- 33 Jones (2004); Harvey (2005); Rosset (2006).
- 34 Speth (2009).
- 35 Harvey (2005); Klein (2008).
- 36 Oates (1999); Terborgh (2004).
- 37 Wright and Muller-Landau (2006).
- 38 García-Barrios et al (1991).
- 39 Davis (2001).

- 40 Moore Lappé et al (1998).
- 41 The displacement of small-scale farmers from the countryside, the dependence on imported foodstuff, droughts and other climate-related disruption to agricultural production, and an increase in consumption in rapidly developing countries like China and India have caused major disruptions to local food systems, especially in the Global South, and have generated a food crisis toward the end of the first decade of the 21st century. However, this food crisis is not based on the absolute amount of food, since the world as a whole still produces more food than is necessary to feed the world population. This issue is discussed further in Chapter 6.
- 42 Green et al (2005); Vandermeer and Perfecto (2005b); Perfecto and Vandermeer (2008a).
- 43 Angelsen and Kaimowitz (2001a, 2001b).
- 44 cf. Anderson and Grove (1987); Johnston (1994); Adams and McShane (1997); Guha and Martinez-Alier (1997); Zimmerer and Young (1998); Hall (2000); Rothenberg and Ulvaeus (2001).
- 45 Barraclough and Ghimire (2000).
- 46 Barraclough and Ghimire (2000).
- 47 The most recent and most analytically convincing review can be found in Hochstetler and Keck (2007, chapter 4). Other useful overviews include: Ozorio de Almeida (1992); Moran (1996); Hall (2000); Carvalho et al (2002); Nepstad et al (2002); Wright and Wolford (2003, chapter 4); Brown (2006a, 2006b); Brown et al (2007).
- 48 Hemming (2004); Mann (2005); Heckenberger et al (2008).
- 49 Hecht and Cockburn (1989); Ozorio de Almeida (1992); Browder and Godfrey (1997); Hall (2000); Wright and Wolford (2003).
- 50 Browder and Godfrey (1997).
- 51 Bunker (1985); Hecht and Cockburn (1989); Rich (1994).
- 52 Foresta (1991).
- 53 Durham (1979).
- 54 Browder and Godfrey (1997); Moran et al (2000); Carvalho et al (2002).
- 55 Rich (1994).
- 56 Hecht and Cockburn (1989); Revkin (2004); Hochstetler and Keck (2007).
- 57 Bunker (1985); Hecht and Cockburn (1989).
- 58 Hochstetler and Keck (2007).
- 59 Hall (2000); Moran et al (2000); Carvalho et al (2002); Hochstetler and Keck (2007).
- 60 Whitesell (1993, 1996); Brown and Purcell (2005); Brown (2006a, 2006b); Brown et al (2007).
- 61 Brown (2006a, 2006b); Brown et al (2007).
- 62 Nepstad et al (2002).
- 63 It has been argued that neo-liberal policies that can lead to some level of industrialization and massive migration from rural to urban areas or centres of employment (like *maquilas* in Mexico and Central America), can reduce deforestation, as they did in Puerto Rico during the industrialization period of the 1950s and 1960s (Aide and Grau, 2004). However, Puerto Rico is a very special case because of the colonial relationship of the island with the US that facilitated the migration of the 'excess' population to the US, and provided federal funding to support such a massive displacement without major political upheaval.

- 64 Some improvements have been achieved under the government of Luis Inácio Lula da Silva. However, by most measurements of inequality, Brazil is still amongst the most unequal countries on the planet (CEPAL, 2006).
- 65 A longer, heavily annotated version of the summary that follows may be found in Wright and Wolford (2003, chapters 1 and 3).
- 66 Ondetti (2008; pp229ff).
- 67 Bunker (1985); Hecht and Cockburn (1989); Wright and Wolford (2003).
- 68 See websites of the MST (www.mst.org.br/mst/home.php) and Friends of the MST (www.mstbrazil.org) for a variety of statements on these issues over the last several years.
- 69 Ownership is not an evident category, but its full discussion goes beyond the intentions of this book.
- 70 Barraclough and Ghimire (2000); Wallerstein (2004).
- 71 There are obviously exceptions, such as the Great Depression.
- 72 Johnston (1994); Adams and McShane (1997); Nepstad et al (2002); Purcell and Brown (2005).
- 73 Bonner (1993); Adams and McShane (1997); Neumann (1998).
- 74 cf. Anderson and Grove (1987); Johnston (1994); Sponsel et al (1996); Guha and Martinez-Alier (1997); Zimmerer and Young (1998); Rothenberg and Ulvaeus (2001); Brockington et al (2008).
- 75 Joppa et al (2008).
- 76 Wright and Wolford (2003).
- 77 Wright (2005).
- 78 Ross (2000).
- 79 Thompson (2001).
- 80 Barraclough and Ghimire (2000).
- 81 Keynesianism is based on the ideas of 20th-century British economist John Maynard Keynes. According to Keynesian economics the state should stimulate economic growth and improve stability in the private sector – by, for example, adjusting interest rates and taxation, and funding public projects (http://en.wikipedia.org/wiki/Keynesian_economics).
- 82 Pretty and Smith (2004); Bacon et al (2005); Cullen et al (2005); Campos and Nepstad (2006); Bawa et al (2007).
- 83 Fernside (1993).
- 84 Kaimowitz (1996).
- 85 Tucker (2000); Vandermeer and Perfecto (2005a).
- 86 Vandermeer and Perfecto (2005a).
- 87 Hecht and Cockburn (1989); Ozorio de Almeida (1992); Sponsel et al (1996); Tucker (2000); Vandermeer and Perfecto (2005a).
- 88 Moran (1996); Wright and Wolford (2003).
- 89 Desmarais (2007).
- 90 Wright and Wolford (2003).
- 91 Cullen et al (2005).
- 92 Goulart (2007).
- 93 Oates (1999); Rabinowitz (1999); Wilshusen et al (2000); Brechin et al (2002); McShane and Wells (2004); Terborgh (2004).
- 94 Joppa et al (2008).
- 95 Rosset (2006).
- 96 Barraclough and Ghimire (2000).

Coffee, Cacao and Food Crops: Case Studies of Agriculture and Biodiversity

Biodiversity, agriculture and social movements are the components of our argument, as discussed in the previous three chapters. With each of those issues, we peppered our discussion with particular examples. However, such peppering may have left the reader with a sense that the real world conforms to our perspective only in these anecdotal ways. In this chapter, we offer three extensive case studies. The first, the coffee agro-ecosystem, we discuss as an example of how an agro-ecosystem can be constructed in different ways and how that construction indeed does affect biodiversity. We choose this example partly because we have extensive experience doing research in the coffee agro-ecosystems of Central America and Mexico, but mainly because probably more than any other agro-ecosystem, a wealth of data are available on the consequences of management intensity for biodiversity.

The second case study is the cacao system. While less is known of the details of the biodiversity consequences of different management systems, a great deal is known of how socio-political forces have shaped the cacao landscape in Brazil. It thus represents a case study that reflects the need for a detailed knowledge of the history and socio-political structure of the agro-ecosystem of concern.

The third case study is not so much an example as an acknowledgement that food production rather than drugs (caffeine and theobromine) is the most important aspect of agriculture. An examination, even if superficial, of how the production of grains might relate to our story is thus warranted.

COFFEE AND THE TECHNICAL SIDE OF BIODIVERSITY

As we explained in Chapter 2, there is now little doubt that isolating fragments of natural vegetation in a landscape of low-quality matrix, like a pesticide-drenched banana plantation, is a recipe for disaster from the point of view of conserving biodiversity. That isolation effectively reduces the migratory potential that is needed if the metapopulations of concern

are to be conserved in the long run. Whatever arguments exist in favour of constructing a high-quality matrix, and there are many, the quality of the matrix is perhaps the critical issue from the point of view of biodiversity conservation. The concept of 'the quality of the matrix' must obviously be related to the natural habitat that is being conserved, but most importantly, it involves at its core the management of agricultural ecosystems. The matrix matters!

One of the best-studied cases of a matrix that matters is the coffee agro-ecosystem. The importance of this ecosystem for biodiversity conservation is twofold. First, it is an important habitat for biodiversity *per se*. Second, it is important as a high-quality matrix through which organisms can migrate from patch to patch of natural habitat. Third, it represents a matrix ecosystem in which it can be demonstrably shown that biodiversity has a potentially important function with regard to the normative goals of management in the ecosystem. We treat each of these three issues below, followed by some socio-economic speculations associated with the complicated issue of certification and coffee prices: topics intimately related to biodiversity conservation.

Coffee agroforests as habitats for biodiversity

In the northern part of Latin America coffee has traditionally been cultivated under the shade of a diverse tree canopy. Having been domesticated from the understorey of forests in northeastern Africa and therefore adapted to live in shaded environments, it was most naturally planted in the understorey of natural forests when first domesticated in Latin America. Soon it became common to plant coffee in non-forested areas, while simultaneously planting trees to provide shade. These traditional shaded plantations are characterized by a high planned biodiversity, including coffee, shade trees and fruit trees. Most importantly, we now understand that they also include an enormous amount of associated biodiversity.¹

This pattern of planting shade trees along with the coffee was characteristic of the major coffee-producing countries from Mexico to Peru. Elsewhere, notably in Brazil, the pattern was distinct. Due to historical accident, Brazil initiated its coffee history with 'sun' plantations and today has the largest extensions of 'sun coffee' in the world. Our account in this particular chapter focuses on the experiences of northern Latin America, with only occasional reference to Brazil and other countries.

In order to quantify some of the associated biodiversity in traditional plantations, we sampled insects in the canopy of individual shade trees in a traditional coffee farm in Costa Rica.² The results of this study were astonishing. We were expecting high levels of diversity but nothing like what we found. From a single canopy of a small shade tree in a small traditional plantation we collected 126 different species of beetles! This level of species richness was within the same order of magnitude as in the canopy of large trees in a Panamanian rainforest.³ Even more surprisingly, a

second tree yielded another 110 species of beetles, 86 per cent of which were different from those collected from the first tree. Subsequently many other researchers have documented high diversity of birds, mammals, plants, insects and other organisms in these traditional coffee plantations.⁴

There is no doubt that coffee agroforests provide habitat for a large number of organisms. Perhaps these managed systems are not able to maintain viable populations of jaguars or other charismatic megafauna, although there is at least one report of a tiger encountered in a traditional coffee plantation in India.⁵ However, they are certainly adequate for large numbers of birds, small mammals, epiphytic plants and invertebrates. But what is most important, they provide habitat for these diverse organisms while at the same time providing a livelihood for farmers, as we discuss below.

Intensification and the loss of biodiversity

In the 1980s, a programme to intensify coffee production was launched in most of the northern Latin American countries. By the 1980s these countries had accumulated a large external debt and were pressured by international lending agencies to increase their revenues in order to service it. USAID (the US development agency) provided 81 million US dollars to finance a programme for the 'modernization' of coffee production.⁶ The programme consisted of providing incentives to coffee farmers to 'intensify' coffee production by incorporating new varieties of coffee that could grow well without shade trees, thus increasing yield on a per area basis. The coffee intensification programme consisted of a technological package that included not only the new coffee varieties but also fertilizers and herbicides that could substitute for the most obvious functions of shade trees – provisioning of nitrogen through their association with nitrogen-fixing bacteria in their roots and reduction of weed growth through the shade they cast. The programme met with variable levels of success, with Colombia and Costa Rica experiencing far more success than other countries in convincing producers to shift to the more intensive system. As a result of the variable success of this programme we now have a variety of coffee production systems in northern Latin America.

Patricia Moguel and Victor Toledo have developed a classification system that is now widely used to characterize coffee systems (Figure 5.1).⁷ Rustic coffee is the most diverse and densely shaded and consists of coffee that is planted under the canopy of a previously existing forest. Traditional polycultures (or 'coffee gardens') have a high diversity of planted shade and fruit trees with a heterogeneous canopy. Although coffee is the main cash crop in this system, farmers produce many other products for sale or family consumption within these coffee gardens. Commercial polycultures are less diverse than traditional polycultures and focus on commercial crops, especially coffee and sometimes fruit trees. The last two systems are the most intensive and less diverse systems. Shaded monoculture is a

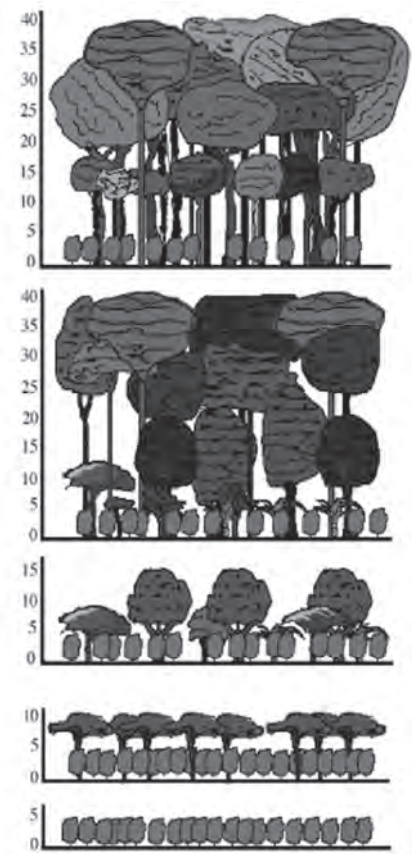


Figure 5.1 *Diagram of the coffee intensification gradient*

Note: Top panel represents coffee planted under natural forest canopy, usually referred to as rustic coffee. Second panel represents a traditional polyculture containing a mixture of shade trees that are allowed to grow tall. Third panel represents a commercial polyculture in which shade/fruit trees are naturally relatively short or are pruned regularly. Fourth panel represents a monoculture of shade. Fifth panel represents a monoculture of coffee, frequently referred to as ‘sun coffee’.

Source: Moguel and Toledo (1999)

shaded system in which the shade trees are sparsely planted and belong primarily to a single genus or species. Finally, the most intensive system is the unshaded monoculture, frequently referred to as ‘sun coffee’. Although this classification does not make any reference to the use of agrochemicals, the tendency is for the more intensive systems (shaded and unshaded monocultures) to use more herbicides and synthetic fertilizers than the other systems.



(a)



(b)

Figure 5.2 *Two types of coffee plantation: (a) shaded polyculture and (b) monoculture or 'sun coffee'*

Source: Ivette Perfecto

We were in Costa Rica when many farmers were in the process of transforming their plantations from traditional polycultures (Figure 5.2a) to 'sun coffee' (Figure 5.2b). Knowing that the traditional coffee agroforests contain such a high biodiversity we could not help but ask where all that biodiversity would go when the process was completed. And, of course, we found it curious that most conservationists simply ignored this massive programme of what was effectively deforestation.

As introduced in Chapter 2, among the most important and least studied patterns of biodiversity is the relationship between agricultural intensification and biodiversity. We know that a natural forest contains more diversity than an intensive agricultural monoculture. We also know that the process of agricultural intensification results in a dramatic reduction in the planned biodiversity (the crops and animals that the farmer intentionally includes in his or her farm). However, we know little about the pattern of biodiversity loss along the intensification gradient for most agro-ecosystems. In the case of coffee production, the diversity of production systems enables us to examine this issue. A variety of studies comparing 'sun coffee' with 'shade coffee' or with coffee with different levels of shade have shown that the intensification of this agro-ecosystem results in a loss of biodiversity for most organisms that have been examined.

Birds have been the focus of many of these studies. Indeed the intensification of coffee has been implicated in the decline of several migratory species, since their winter feeding grounds were the shaded coffee farms that were deforested. Even so, the negative impact of intensification seems to be stronger for resident birds, presumably because they tend to have more specialized food and habitat requirements than most migrants. Coffee intensification not only reduces bird diversity but also changes the composition of the bird community by favouring birds that are more characteristic in open habitats – what bird-watchers refer to as 'tramp' species or 'weeds'.

With a few exceptions, insects and other arthropods also decline with the intensification of coffee. For example, reviewing studies of the effect of coffee intensification on ant diversity, we encountered 21 published studies, 18 of which showed a significant decrease in ant diversity with intensification.⁸ Since the intensification process results in a reduction of tree density and diversity, a sharp reduction of arboreal species should not be surprising. What is surprising is that organisms that live strictly on the ground are also affected by intensification. Recently, an important experiment was conducted with ants that nest in hollow twigs on the ground. When given a choice these ants select a diverse habitat over a monotonous one. What is interesting about this study is that a higher diversity of ants in the diverse habitat did not result from particular species of ants preferring distinct kinds of twigs, but rather it seems to be that ants select diversity itself – diversity in tree species begets diversity in ants. The specific details of how a diverse assemblage of shade trees (the source of the twigs) is more attractive than a less diverse assemblage remains enigmatic.⁹

The few studies that have examined a gradient of shade suggest that the particular type of shade is also important. Some species of shade trees support higher diversity and abundance of arthropods than others. Furthermore, there is no reason to think that the pattern of 'species decline' with increased intensification should be the same for different

kinds of organisms. Although comparative studies that include different taxa within the same sites are rare, our knowledge of the natural history of different groups suggests that some organisms are more susceptible to intensification than others. This is evident for birds, where residents have been shown to be more susceptible to intensification than migrants. Our own data from a study in Mexico shows that ants and butterflies follow a very different trajectory of richness decline along an intensification gradient, with butterflies declining rapidly even with a low degree of intensification, whereas ants are far more resistant to the effects of intensification, declining in biodiversity only after the intensification process has reached a relatively high level. Such differences represent an important challenge to establishing criteria for certification of 'shade coffee' for conservation purposes, as will be discussed later in this section.

Coffee agroforests as a high-quality matrix in the landscape

In Latin America, coffee is produced mainly in the highlands at middle elevations. Frequently the entire landscape of the coffee-growing regions is dominated by coffee plantations (large and small) with interspersed fragments of forest in areas that are too steep for cultivation or in the riverbeds where they are protected by law. In southern Mexico, most of the areas designated by the government as high priority for biodiversity conservation are embedded within a matrix of coffee plantations.¹⁰

As was discussed previously, most natural ecosystems in today's world are highly fragmented, and where coffee is produced in the Americas is no exception. In these fragmented landscapes, many organisms are likely to persist as metapopulations. Biodiversity conservation at the landscape level depends on the maintenance of that metapopulational structure, which is affected not only by rates of local extinction but, more importantly, by rates of migration through the matrix. If the matrix consists of a 'sun coffee' monoculture, it could deter the inter-fragment migration of many forest species. On the other hand, if the matrix is a traditional shaded plantation, it may facilitate migration from patch to patch, and therefore maintain the metapopulational structure of some species.

It is important to note that the matrix does not need to provide a habitat of enough quality for the permanent establishment of a species. The matrix only needs to provide a habitat benign enough for individuals to move through. For example, in the site where we have been studying coffee systems in southern Mexico, there are two relatively large forest fragments that exist within a matrix of shaded coffee agroforests. Local bird-watchers have spotted the highland guan,¹¹ a large forest bird that reportedly needs a fairly old-age forest to survive and that is listed as a threatened species by the International Union for the Conservation of Nature.¹² However, it is almost certain that neither of these forest fragments is large enough (one is about 15 hectares, the other about 40) to maintain a highland guan

population in perpetuity. Thus the only chance for the species to survive is as a metapopulation within fragments of mature forest scattered amongst the coffee farms. But for this to be possible, the highland guan needs to be able to cross from one forest patch to another through the coffee matrix. The good news is that this species has been observed, very rarely, in shaded coffee plantations. Given that this species needs fairly well-developed forest to survive, it was almost certainly just moving through the shaded plantation when sighted there, perhaps in search of fruits or something else to eat. Once an individual highland guan ventures out of one of the forest fragments, there is a fixed probability that it may end up in another fragment where a new subpopulation can be established. This process, in effect, could maintain the metapopulation structure needed for the maintenance of this species. Given what we know about the behaviour and ecology of the highland guan, it is very unlikely that an individual would venture into a 'sun coffee' plantation. So, if 'sun coffee' plantations surrounded the small subpopulations of the highland guan, the overall population would be doomed to extinction. Shaded coffee farms, we propose, provide the necessary high-quality matrix that allows migration of this species thus making its long-term survival more likely. Without that matrix, the highland guan would be expected to go extinct in successive forest patches, until it became extinct over the whole region.

Charismatic fauna, like the highland guan, is not all, or even the most important fauna to benefit from a high-quality matrix. Studies of ants suggest that shaded coffee plantations are a high-quality matrix that can contribute to the maintenance of high diversity at the landscape level. Studying the species-richness of ants within a forest fragment and at various distances from the forest edge into the coffee matrix we discovered that ant species-richness declines sharply as you move into an intensively managed coffee monoculture. On the other hand, as you move away from the forest edge into a shaded polyculture, ant diversity declines far less and far less rapidly, remaining relatively high at long distances from the forest (up to 800 metres).¹³

In the case of ants, as with any other organism, we repeat that it is not necessary for the matrix to provide a habitat that can sustain the population in perpetuity. The matrix could be only a transitory habitat for many species that may only have viable populations in the landscape as a whole, with the key habitat being the fragments of natural habitats, but the matrix being essential for migration. Thus, we suspect that many of the ant species that were collected in the diverse shaded plantation were actually forest specialists. Ant colonies go through a process of colony building during which only unfertile workers (all female) are produced. Once the colony reaches maturity, it starts producing fertile males and females with wings, which then fly away from the colony, encounter flying individuals of the same species from other colonies, and mate. Fertilized females ('queens') then start searching for a place to establish a new colony. Depending on the inter-patch distance, the queen may be able

to make it all the way to the next patch of forest. However, if the patches are too sparse, the queen may not be able to reach another forest patch and may land in the matrix. Once in the matrix, she will start looking for a nesting place. The chance that she will find a good nesting site, establish a colony and reach the point at which new queens are produced, is most certainly higher in a shaded plantation than in 'sun coffee'. Even though the species may not be able to survive over the long term in a shaded plantation, it is possible that individual colonies can survive to the point that they produce new queens that will mate and fly away in search of a good nesting site. Through this process, some queens will eventually land in another patch of forest where the colony can survive for a long period of time, probably in the presence of other colonies of the same species in a viable subpopulation, in effect completing the process of inter-patch migration that is necessary for maintaining a metapopulation structure. As in the case of the highland guan, the quality of the matrix is the main determinant for the maintenance of biodiversity, even with species that seemingly require natural forest for long-term survival. Without migration between patches, many of the forest species will be doomed to extinction at a larger regional level.

In Mexico, the government has identified areas of priority for conservation and, in southern Mexico, most of these areas are located in coffee-producing areas. From our discussion above we hope it is clear that the quality of the coffee matrix is exceedingly important for biodiversity conservation within the remaining fragments of natural forest. A matrix that consists of nothing more than 'sun coffee,' with the almost inevitable use of pesticides therein, could easily result in extinction of forest species. Since many of the species in this region are endemic, their local extinction is the same as their global extinction. A conservation programme that focuses on preserving forest patches without paying attention to how coffee is produced in the surrounding areas will fail in the long run, probably resulting in the global extinction of many species. In this situation it is imperative that conservation policies are based on a landscape perspective that includes the coffee matrix as well as the patches of forest.

The 'function' of biodiversity in the coffee agro-ecosystem

A shaded coffee plantation with many singing birds, large shade trees covered with different kinds of epiphytes and a high diversity of other organisms can be a most aesthetically pleasing sight, and feed the soul of the farmer. But can it help her produce more and produce more sustainably? An important scientific question to ask about a managed ecosystem like coffee is, 'what is the function of biodiversity?' It turns out that this is a surprisingly complicated question. Can a diverse array of organisms help increase the productivity of the agro-ecosystem? Or, would it be better, as some agronomists propose, to select those species, and only those

species, which are the most efficient, and eliminate the rest, which are only competitors? We propose that the high diversity of organisms found in coffee plantations can play an important role in the functioning of that agro-ecosystem. Recent debates on the role of biodiversity in ecosystem function suggest that we should be cautious in making general statements about biodiversity and ecosystem function.¹⁴ Nevertheless, the question is an important one for the farmer. One ecosystem function that has long been associated with biodiversity is the regulation or control of insect pests. However, the relationship between pest management and biodiversity is complicated and requires a system-by-system analysis. In this section we present three examples of the role of biodiversity in the regulation of potential insect pests in coffee, even as we emphasize that control of pests is only one 'function' of biodiversity.

Ants and the coffee berry borer

One of the main coffee pests in the Americas is the coffee berry borer (CBB), a tiny beetle (about the size of a pinhead), accidentally introduced from Africa. The female adult beetle bores into the berry and enters the seed. Inside, she lays eggs, the eggs hatch, and the larvae eat the insides of the seed. They complete their life cycle within the seed, adults mate and the fertilized females leave the berry in search of new berries where they can lay their eggs and start a new cycle. The CBB significantly reduces coffee yields and is currently considered the worst insect pest of coffee in the region. Since this pest is not native to the Americas, it does not have any specialized natural enemies that can control it efficiently. Introductions of an African parasitic wasp and some general fungal pathogens seem to suppress the population but do not control it completely. However, recently it has been discovered that ants prey on the CBB. In Colombia, several ant species have been seen removing borer adults and larvae from the fruits that were sun-drying after harvest. Also, Moises Velez from the National Coffee Research Center (Cenicafé) observed how a relatively large ant actually 'hunted' the adult beetles as they alighted on a berry or when they were exiting the berry to infest another, an observation repeated by us in Mexico as well. Individuals of this ant were observed waiting on a berry for adult CBBs to emerge from the seeds, grabbing and immobilizing them with a sting, and taking them to their nest. It is worth noting that this species of ant has been collected from shaded plantations and forests, but not from 'sun plantations'. The intensification of coffee most probably results in the ant's elimination and therefore the elimination of one of the few native natural enemies of the CBB.

It could be argued that while we should try to maintain this species in the plantations, all other ant species are either irrelevant or redundant with respect to CBB control, and there is no need to keep them, at least not with respect to this particular function. However, as mentioned above, the species of concern is a relatively large ant and cannot penetrate into the

seed through the small hole made by the CBB. This means that only the adult beetles can be susceptible to its predatory effect. But there are many other ant species that are small enough to penetrate the seeds and eat the eggs and larvae of the CBB. Indeed, Colombian ecologist Inge Armbrrecht reported 21 ant species preying on the CBB in coffee plantations in Colombia.¹⁵ Some of these species are small enough to enter the holes made by the borers and prey on their brood. She also found that ant predation was a more important mortality factor in shaded plantations than in 'sun coffee' plantations. Taken together, all these pieces of evidence suggest that a high diversity of ants may already be contributing to the regulation of the main coffee pest in Latin America. The problem may be that the extensive 'sun coffee' plantations or less-shaded plantations are providing a refuge for the CBB, where it can escape the predatory effects of the diverse assemblage of predatory ants that live in the shaded farms.

Birds and the trophic structure of arthropods in coffee

Walter Peters, a coffee producer in Chiapas, Mexico, is a bird enthusiast. He plants specific kinds of trees to attract birds to his plantation. He has been observing and recording birds on his farm, Finca Irlanda, since he was young, when his father managed the plantation. One day we were walking with him on his farm and noticed that a shade tree was being defoliated by a heavy infestation of a certain kind of caterpillar. We alerted Walter to this potential pest outbreak but he replied calmly, 'the migrant birds will soon arrive and will take care of that problem. No need to worry.' And indeed, two weeks later, the migrants arrived and took care of the problem. In addition to loving biodiversity for purely aesthetic reasons, he also understood the role of biodiversity in maintaining a healthy coffee plantation.

With the exception of the introduced CBB, there are few other insects that have become pests in the coffee agro-ecosystem in the Americas. Although the caffeine contained within coffee plants is known to suppress herbivores (indeed, caffeine is undoubtedly the result of the co-evolutionary process between coffee plants and their herbivores), this alone does not explain the lack of insect pests in coffee, since there are more than 200 species of insects that are known to eat coffee.¹⁶ A possible explanation for the lack of serious insect pests is that the system harbours a large density and diversity of natural enemies of herbivores, including insectivorous birds.

We decided to test the hypothesis that birds would be able to control insect pest outbreaks within diverse coffee farms, but not within intensive farms where bird diversity and density is lower. We conducted an experiment by constructing bird exclusion cages (with fish netting that prevented birds from entering the enclosure) and adding caterpillar larvae to plants inside and outside the enclosures, simulating a real pest outbreak

in both a diverse and intensive farm.¹⁷ The results of the experiment confirmed Walter's prediction that birds would 'take care' of potential pests. After just 24 hours, more than 75 per cent of the larvae exposed to bird predation had disappeared from the diverse farm.¹⁸ Although some larvae also disappeared from the intensive farm, the numbers were the same outside and inside the exclosures (with and without birds), indicating that birds were not responsible for the disappearance of the larvae. This experiment suggests that the high number and diversity of birds within the shaded plantations provides a sort of buffering mechanism against insect pest outbreaks, just as Walter suggested from his many years of observing birds on his farm.

With these results it is tempting to conclude that birds control all insect herbivores in coffee plantations. However, Nature is seldom so simple. Through detailed studies of the trophic structure (who eats whom) of the coffee agro-ecosystem we have discovered that birds appear to have a positive effect on coffee plants, though through a complicated chain of indirect effects. Basically, it seems that under normal circumstances birds eat a large number of spiders (especially web-spinning spiders). In turn, the spiders normally capture a large number of the very small parasitic wasps that become entangled in their webs. But the parasitic wasps mainly attack the herbivores that eat the coffee. Through this five-level food chain, that includes 'intraguild predation' (carnivores eating other carnivores), the indirect effect of birds on the coffee plants is thus positive (Figure 5.3). The potential pests are controlled by the parasitic wasps, but the wasps are attacked by the spiders, which means the spiders actually have a negative effect on the coffee. But then the birds seem to prefer eating the spiders, thus releasing the wasps to prosper better and control the potential coffee pests. However, since birds seem to prefer larger prey and can also shift their diet according to what is most common, they are also able to respond to the occasional outbreak of specific pests.

In the tropics, there are also many insectivorous bats, and we have found that they have similar effects to the birds.¹⁹ Using exclosures that were on plants just during the day, or just at night, or both day and night, or at neither day nor night (a control), we were able to demonstrate that bats play a complementary role to birds in terms of regulating insects in the coffee plantations. Furthermore, it appears that bats are even more important than birds during the wet season, when the migratory birds are in their northern breeding grounds.

The ant, the scale and the beetle

If the effects of birds and bats on potential coffee pests seems complicated, it is nothing compared to other interactions in the coffee agro-ecosystem. Consider the case of the *Azteca* ant.²⁰ This species of ant nests in the shade trees in the coffee farms of Mexico and is well known to the coffee workers as a nasty stinging ant. When you disturb a nest, thousands of workers

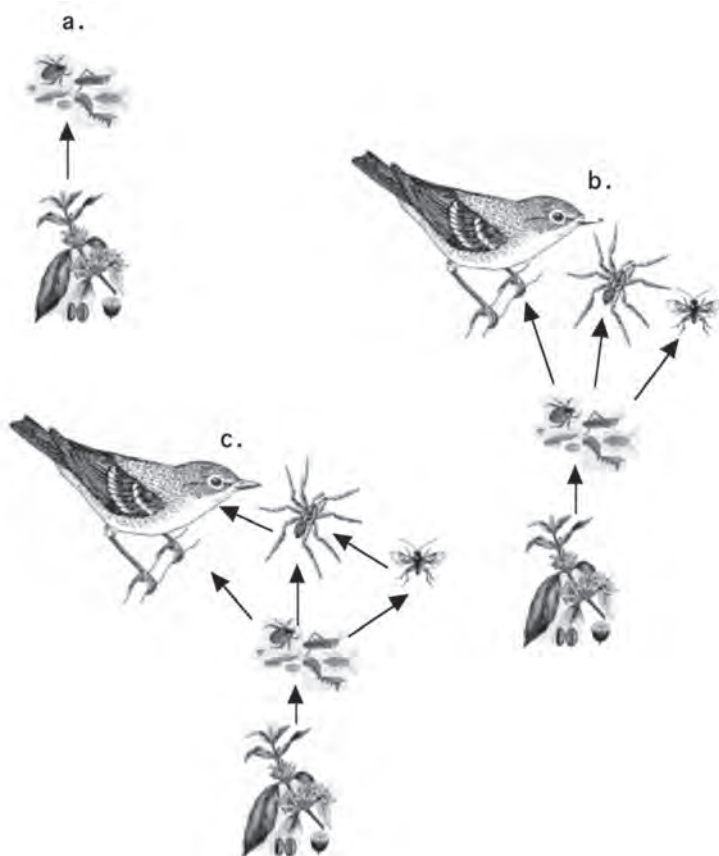


Figure 5.3 *Effects of birds on coffee through a complicated food web*

Note: (a) A variety of insects (over 100 are known) feed on coffee leaves or berries and are thus potential pests of coffee. (b) Predators and parasites are normally thought of as natural controllers of these potential pests, ensuring that their population densities remain below the levels at which they would be considered to be pests. (c) But it turns out that the system is far more complicated in its operation with birds eating the spiders that also eat the herbivorous insects, but the spiders also trap the parasitic wasps in their webs. Thus the question arises: are birds good for biological control because they eat the herbivores that eat the coffee? Or are birds bad because they eat the spiders that would ordinarily eat the herbivores? Or are birds good because they eat the spiders that eat the parasitic wasps which would ordinarily eat the herbivores? These sorts of complications exist in all ecosystems, but are particularly important in agro-ecosystems where habitat modification could either promote or deter the presence of birds.

Source: Authors' elaboration

boil out of the tree and begin stinging. But far worse is the apparent effect these ants have on the coffee trees. While they do not build their nests in the coffee tree themselves, they frenetically move around tending scale insects on the coffee trees that are adjacent to the shade tree where they nest (Figure 5.4). This is a remarkable relationship, well-known around the world, in which the small, immobile scale insects produce a sweet secretion called honeydew which provides nourishment for the ants. While the ants are frenetically running around eating the secretions of the scale insects, they are also protecting the scales from the many small parasitic wasps and ladybird beetles that would otherwise attack and decimate the population of scale insects. The relationship is called 'mutualism' and, generally speaking, is the most common interaction of species we see in

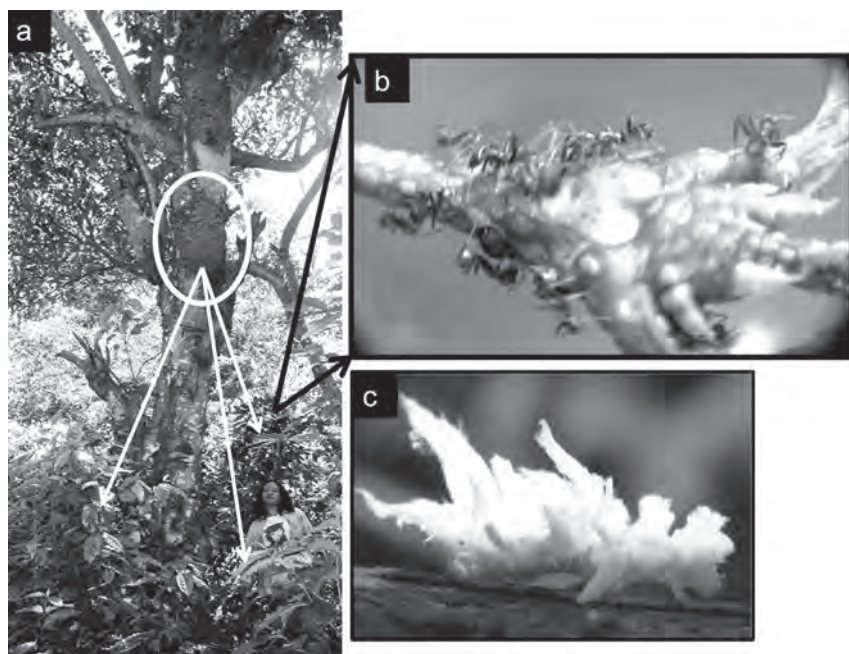


Figure 5.4 *Azteca ants tending the green coffee scale on a coffee plant*

Note: (a) The ant, *Azteca instabilis*, nesting in a shade tree and tending the scale insects, *Coccus viridis*, on coffee bushes (one of the authors, Ivette Perfecto, is standing next to the shade tree). b) A close-up of the ants tending the scale insects in a coffee branch. The scale insects produce honeydew to feed the ants and in turn the ants protect the scale insects from their predators and parasites. c) Predatory larvae of the ladybird beetle, *Azya orbiger*. The larvae prey on the scale insects and is immune to ant predation because of the white waxy filaments that cover its body.

Source: (a) John Vandermeer; (b) Shinsuke Uno; (c) Ivette Perfecto

Nature, from insects that pollinate plants, to the bacteria that live in our stomach and help us digest food. In the specific case of ants and many different species of sap-sucking herbivores, like aphids and scale insects, the herbivores suck the juices out of plants, and part of what they do with these juices is produce the honey-like substance that they excrete to 'feed' the ants that protect them.

In the coffee plantations there is a particular species of scale insect (its formal name is *Coccus viridis*, but we will continue referring to it simply as 'scale') that is well known to become, at times, a devastating pest of coffee and other agricultural plants, like oranges and grapefruits. There is no doubt that where it does occur on the coffee tree, it causes significant decline in yields of those particular bushes. So, if the ant population is very common in the plantation, one might expect the scale insects to be a major pest. And, if there are no ants, one would expect the scales to disappear. So, a typical agronomist might see the ants as a potential pest of the coffee, worthy of all efforts necessary to eliminate it.

But the function of biodiversity is never simple, and this example is no exception. We take one particular coffee farm, Finca Irlanda, as an example here. On that farm, only approximately 3 per cent of the shade trees are occupied by *Azteca*, which means that on 3 per cent of the plantation, the scales dramatically affect the coffee trees. Naturally, there should be concerns about the ants expanding their area and possibly occupying more of the shade trees, such that, for example, if they ever got to a level of over 50 per cent, we would possibly be facing a massive decline in coffee yields. But this brings up the question as to why the *Aztecas* occur in such a small portion of the plantation. One possible reason may have to do with a very small fly. The fly is a parasite of the ant. The female fly lays an egg on the ant and the fly larva develops inside the ant's head, eventually eating out all the tissue and causing the ant's head to drop off. For this reason, these flies are known as 'decapitating flies.' It seems that, in a shaded coffee plantation, the ants have a more-or-less balanced relationship with the flies, such that the ants can increase the area where they live, but if they ever become too common, the decapitating flies start to build up their populations and, in classic predator-prey fashion, the prey (in this case the ants) have their populations controlled. So, the 3 per cent of the trees occupied seems to be a consequence of the controlling force of the decapitating flies.²¹

But the story does not end here. A species of ladybird beetle that normally eats scale insects also lives in the system. This sort of beetle is well known to be a devastating predator of the scales, which is obviously one of the reasons the ants are necessary, from the point of view of the scales. Close examination of the beetle larva reveals that it has waxy protrusions all over the surface of its body, which makes it immune to the attacks of the ants (Figure 5.4c). It thus can live on the scale insects, even though the ants are protecting those scale insects from other natural enemies that are trying to eat them, including the adult beetles. Furthermore, at least three

different species of parasitic wasps also attack the beetle larvae. However, when the beetle larvae are in areas where the ants are protecting the scales, the harassing action of the ants also prevents these parasites from attacking the beetle larvae. Therefore, the beetles are found almost exclusively in areas where the ants are tending the scales, taking advantage of the non-intended protecting effect of the ants. It is a well-known problem amongst biologists who try to cultivate this type of beetle that it is difficult to get populations of beetles surviving in the laboratory because almost all the beetle larvae you find in the field contain parasitic wasps inside them, and thus die shortly after being brought into the laboratory.

But the irony is that the adult beetles are not protected from the ants as the larval beetles are, with their waxy secretions (Figure 5.4c). Thus, if they stay in an area where there are ants, they can't get enough to eat. So the adult beetles have to travel outside of the ant areas in order to find food. Thus we have the surprising situation where the beetle larvae cannot survive except when with the ants, and the adult beetles cannot survive except when not with the ants.

We now understand that the adult beetles, as efficient biological control agents, are responsible for keeping many of the potential scale pests under control over most of the plantation. Yet if the ants did not exist in a small percentage of the plantation, all the beetle larvae would be parasitized and die, and their population could not be maintained. Since the ants only occupy about 3 per cent of the plantation, their contribution to yield reduction is trivial compared to their contribution to biological control over 97 per cent of the farm.

So what we have is a system that, on superficial examination, appears to be quite negative for the production goals of the farmer – a species of ant that protects a scale insect that is known to be a devastating pest of coffee. However, upon closer examination, it turns out to be a biodiverse system with complex interactions that actually functions to control this pest, and probably many more. A system of at least eight species of insects is involved: the ant, the parasitic fly, the scale insect, the parasitic wasp of the scale, the beetle and the three species of parasites of the beetle. And these species create this functional system. A superficial reading of the system (ants = scales = bad) could have led to a disastrous management recommendation – to eliminate the ants – which would have resulted in elimination of the main controlling agent of the scales (and perhaps other potential pests), the beetles. In this example, biodiversity has a function, and that function is achieved through complex ecological interactions.²²

Coffee prices, biodiversity preservation and free market fundamentalism

The island nation of Timor-Leste (East Timor) was finally liberated from its imperial master, Indonesia, in 1999. The recent history of this country is an extremely sad account of the developed world either ignoring East

Timor's plight or actively collaborating with a corrupt imperial power in Jakarta. The massive looting and murder committed by the Indonesian military following East Timor's vote for independence shall forever blot the already soiled records of the world's developed countries. If ever there was justification for military intervention, the Indonesian military provided it with their genocidal activities in East Timor. Yet no such aid was forthcoming. East Timor produced coffee, not petroleum.

In a sad footnote, once the developed world did take action, they sent something that seems to have only exacerbated this poor nation's plight. They sent technical advisers. While it may have seemed obvious to those of us less well trained in conventional economic theory, the technical advisers did not focus on the abundant small farmers who potentially could have produced food for the whole country. Instead, they focused on the export sector, as they always seem to do in the neo-liberal age. The major export of the country was coffee. The technical experts, rather than trying to improve the lives of small farmers, decided to recommend the technification of coffee production. Thus, with a focus on 'modernizing' coffee production, East Timor entered a world market already saturated by overproduction (the main current problem in world coffee markets), thanks to the international technical advisory community's advice to Vietnam, Indonesia and other countries. The glut of coffee beans on the market creates extremely low prices (something that, remarkably, seems to always surprise technocratic agronomists) and, while not filtering down to consumers, has caused a severe crisis for coffee farmers the world over. East Timor did not escape this devastation. In 2001, over 80 per cent of villages reported food shortages.

While there is substantial evidence that 'shade coffee' represents a potentially high-quality matrix with regard to biodiversity preservation, the current world politico-economic climate is hardly conducive to its promotion, as the situation in East Timor so clearly demonstrates. Yet the problem is not unsolvable if the world is willing to open up to a slightly different economic focus. The problem has been, since the end of the Cold War, a fundamentalist philosophy in both international economics and technological research. We recall an international meeting we attended in Costa Rica in 1990. Economists, sociologists and development experts all completely agreed that the main, and perhaps the only, problem in the coffee sector was overproduction. There was simply too much coffee being produced, and this resulted in an oversupply, which resulted in low prices. There was no debate about this issue. Walking out of the meeting, which was held within the facilities of the main coffee research station in Costa Rica, we talked with the agronomists working in the station about their research projects. When we asked them what the main goal of the coffee research programme in Costa Rica was, they told us 'to increase production'! There is an enormous discrepancy between the recommendations of the experts – to increase coffee production – and their own analysis about the main problem – overproduction.

Biodiversity conservation and coffee technification are clearly at odds, as we have argued. Growing out of this contradiction has been a new niche in the speciality coffee market. Bird-friendly coffee, or 'shade coffee', is the latest 'special premium' effort to be added to organic and fair trade coffee. In the mid-1990s, the Smithsonian Migratory Bird Center (SMBC) developed certification criteria for certifying 'bird-friendly' coffee (Figure 5.5a). Other organizations promote a similar message, such as coffee certified as shade-grown by the Rainforest Alliance. Recently, USAID, Conservation International and the coffee company Starbucks launched the Conservation Coffee Alliance in Central America, and we will probably see more of these efforts in the near future.²³

One of the more focused initiatives is the 'Bird Friendly' (BF) coffee programme, based on field-work conducted by researchers at the SMBC. Coffee producers – whether estate or cooperative farmers – solicit an inspection via an application. Any farm evaluated for its shade management must be certified as organic. If the shade component of the coffee area meets the BF criteria, then coffee produced on that farm can be sold as BF in the marketplace. The actual inspection of the shade is carried out by inspectors who have taken a training workshop offered by SMBC staff. More than a dozen coffee importers handle BF coffee in the US and Canada. They, in turn, sell to some 40 roasters who have written agreements with the SMBC to use the BF logo and the Smithsonian name in marketing the coffee. Roasters selling labelled BF coffee pay US\$0.25 to the SMBC for every pound of coffee roasted and sold as BF. These revenues go into a research fund to further studies and education on coffee and migratory bird issues.

While there is general agreement that shade promotes biodiversity, there is much debate over how much and what kind of shade should be recommended. To make serious recommendations about the quality and quantity of shade will require more intensive research – how much shade, how diverse it should be, how high and heterogeneous the canopy should be, must epiphytes be present, should agrochemicals be allowed, etc. Those brands that currently advertise 'shade-grown' have certainly taken a step in the right direction, but in the absence of scientifically based criteria, the move to establish such a premium may initially falter. That does not change the potential for such a premium.

Currently there are three distinct certification schemes for coffee – organic, fair trade and biodiversity-friendly (or 'shade') coffee. Inherent in such a situation is the problem of consumer confusion, which is evident to anyone who has asked for either fair trade or 'shade coffee' and then followed up with the question, 'Is it also organic?' The answer is invariably positive, not because the vendor has even the faintest idea of whether it is true or not, but because there is an underlying assumption that all three are more or less the same thing. Much concern has been voiced about the anticipated problem of 'label fatigue' by some in the coffee industry, and it may in fact come to pass at some point. But thus far we have seen no sign

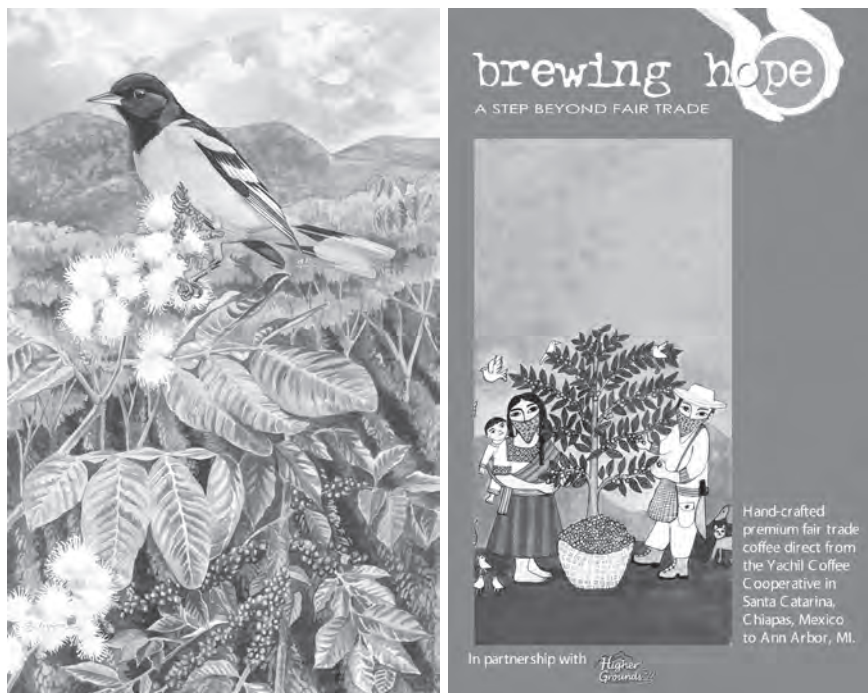


Figure 5.5 Two types of coffee initiative: (a) Smithsonian Migratory Bird Center's promotional poster for 'Bird Friendly' coffee developed to promote management practices that conserve bird diversity in coffee plantations; b) 'Brewing Hope' initiative to establish more direct linkages between coffee producers and coffee consumer.

Source: (a) Artwork by Julie Zickefoose; (b) logo design by Chelsea Wills, artwork by Beatriz Aurora

of it on the part of consumers – only with importers/roasters, and perhaps only with them because they see the issue from two distinct perspectives: first, as a way to differentiate some of their product, take advantage of niche markets and get a foothold in the 'green market' beyond simple organic; and second, as a bother and a nuisance, especially where any true, third-party certification is involved. Such certification usually means an extra cost to the product, and if it also means certification of their own facility (like being certified to handle certified organic coffee in their warehouse or process certified organic coffee in their roasters), then they can be expected to be less than enthusiastic.

An additional idea that has recently been discussed is that of triple certification (certified organic, fair trade, and shade or bird-friendly). We feel that this approach holds much promise and is already moving ahead in the marketplace with a small number of roasters and retailers. The attraction is that it has something for everyone and, in the right market,

does very well. Several years ago, organic and fair trade promoters were actually talking about converging interests (organic was beginning to be interested in social issues, while fair trade was doing the same with environmental issues). However, since each has spent a lot of time and energy getting to where they currently are in developing interest and markets, no serious action was ever taken. The fair trade promoters have begun to talk up the shade angle more recently, but the US office (TransFair USA) has also begun to discuss and explore how to allow estate farms into the fair trade programme – a notion not embraced by everyone, especially cooperative members who have only recently begun to reap any benefits from fair trade.

Our feeling is that triple certification has great potential. Consumers might have a short attention span, but they're not stupid. If presented in short, cogent messages that explain the connections between the social and the environmental arguments, the average coffee drinker can undoubtedly understand the triple certification concept – and if you think about those groups that are 'target audiences' for such messages (social action groups in churches or labour unions; vegetarian and organic devotees; birder associations, etc.) then the message may be even more palatable and likely to be heard.

Whatever the scheme developed for certification there is one issue that is of utmost importance – that of third-party inspection. Just as organic products need to have the production process and all handling post-harvest done by entities which have been inspected and certified as organic, other themes (like shade) need similar certification. Those with vested interests in reaping financial rewards from the certification cannot be the ones assuring the consumer of a coffee's environmental attributes. It's simply not a good model for instilling confidence in the marketplace.

Other possibilities for expanding on environmental and social concerns include various programmes of consumer–producer cooperation; that is, more direct links between producers and consumers. The basic aim is to incorporate the ideas of bio-regionalism and consumer–producer collaboration at an international level. For example, in Ann Arbor, Michigan, a group of university students made contact with a production cooperative in the highlands of Chiapas, Mexico and are busy promoting a direct connection between that cooperative of indigenous coffee producers and coffee drinkers in Ann Arbor. A Michigan roaster purchases coffee at premium prices from the cooperative in Chiapas and markets it under the trade name 'Brewing Hope' (Figure 5.5b). It is an 'international local' affair. In the same way that some organic farmers talk of the importance of the connection between them and their customers, so is the Brewing Hope brand focused on developing that connection at an international level. The coffee drinkers of Ann Arbor will come to know the lives of the coffee producers in the Yachil Xojobal Chulchan cooperative of the highlands of Chiapas, Mexico. Other similar initiatives are growing in other areas of the developed world. We see great potential in this fair market approach.

Finally, it is worth returning to the beginning of this section to recall that, whether one thinks it is good or bad, governments will always be involved. NGOs can do a great deal, but they are ultimately only part of the mix of political structures that are needed to solve environmental problems generally. Elected bodies with accountability to their constituencies must also be part of the overall solution. Government budgets, enforcement policies, judicial systems, etc. can and should be brought to bear against land degradation, and should promote environmental protection and biodiversity maintenance. Governmental setting of coffee prices through market manipulations has a long, if sometimes less than noble, history. There is no reason why it cannot be used on behalf of the cause of biodiversity preservation. Funds set up for price premiums based on production processes could be used to reward good land stewardship. Just as gasoline is taxed in many countries for government coffers, agro-chemical taxes could fund programmes that are environmentally forward-looking. Just as many state fairs in the US award prizes to farmers with the largest hogs or biggest ears of maize, national contests for coffee production within the most ecologically responsible context could provide incentives to growers. There is no lack of ideas, but a great need for political will.

CACAO AND BIODIVERSITY: THE HISTORICAL DEVELOPMENT OF A BIODIVERSITY LANDSCAPE

Brazil's Atlantic Coast rainforest, or *Mata Atlântica*, harbours one of the highest numbers of species of any forest in the world.²⁴ Many hundreds of kilometres of arid and semi-arid country separate it from the Brazilian Amazon and about two-thirds of the plant and animal species that live in the *Mata Atlântica* are not native to the Amazon rainforest. Perhaps most remarkably, the *Mata Atlântica* still retains immense biodiversity comparable to that of any other terrestrial ecosystem in the world in spite of the fact that somewhere between 93 and 97 per cent of its forest is reported to have been destroyed over the last five centuries. One of the reasons it has been able to maintain such high diversity is that some, though not most, of the crops and cultivation techniques used in portions of the forest's range are themselves compatible with high species diversity. In particular, plantations of shade-grown cacao have recently been discovered to have sheltered high levels of biodiversity even during those periods when the plantations were a major source of raw product for the world's chocolate factories. The cacao-growing region has been designated by the International Union for the Conservation of Nature as one of the ten most important 'hotspots' for biodiversity conservation in the world because of the conjoined circumstances of enormously high and significant biodiversity and the powerful forces that could quickly destroy that diversity. How and why this came to be provides rich and

complex insights into how agriculture can play a critical role in preserving biodiversity.

At the southern end of what is called 'the cacao zone' in the southern panhandle of the Brazilian state of Bahia lies the small town of Santa Cruz Cabralia. It is the spot where the Portuguese explorer, Pedro Álvares Cabral, blown off his course on a voyage to India, became the first European to lay eyes on Brazil. As it was Easter Day 1500, he named the mountain peak that was his first sight of Brazil, Monte Pascual (Easter Mountain). Monte Pascual is now a Brazilian National Park that contains one of the larger of the remaining remnants of Atlantic Coast forest that has never been clear cut, as far as is known. Cabral saw little of real economic interest here other than provisions easily harvested from the local forest and freely traded or given by the local inhabitants. He admired the strikingly healthy and beautiful indigenous people who extended their hospitality to his men. After writing some enthusiastic notes on the area and its people, he proceeded to India. As the Portuguese began to settle Brazil three decades later, they also turned their interest away from the low mountains of what would become the southern panhandle of the state of Bahia, and instead settled first in the coastal areas with rich alluvial soils, hundreds of miles to the north. There, they cut valuable dye-woods and timber out of the native forest, burned the rest, and planted sugar cane, and later, tobacco and other crops. These crops were the economic base for the colonial capital of Salvador da Bahia in the province, and later state, of Bahia, and its rival city, Recife, in Pernambuco. The Portuguese plantations virtually obliterated the *Mata Atlântica* in its northern ranges during the colonial period. The colonists did little, however, to destroy the *Mata Atlântica* in southern Bahia.

Early history

Over three and a half centuries, southern Bahia was slowly settled by *fazendeiros* (plantation owners) who established small plantings of sugar cane, fruit trees and subsistence crops in the relatively few level areas near rivers. In the mid-19th century, things began to change, and by the end of the 19th century the region was one of the most profitable agricultural regions of Brazil. A newly lucrative cacao market was based on the increasing world demand for chocolate, as large urban populations in Europe and North America came to constitute a seemingly limitless market for tropical luxury goods: notably cacao, coffee and, a little later, bananas. So much money could be made from cacao in the boom years that competition for land and labour in southern Bahia was fierce, and the region became one of the most violent regions of Brazil, as it remains to the present day. Cacao planters clear cut a great part of the region. The deforestation was so closely associated with violence that Jorge Amado, Brazil's best-selling novelist, who grew up in the region, spoke of the process of settlement of the region in terms of the local phrase, 'derrubando mata, matando gente', that is, 'felling the forest, killing the people'.

Not all of the forest was destroyed, however, and much of it was able to recover to a substantial extent in the form of a particular kind of cacao plantation. The cacao tree is a native of the rainforest, with one line of descent coming from the Amazon and another from the tropical forests of Central America and southern Mexico. It is an understorey tree, growing to about eight metres in height and flourishing naturally under a higher canopy of larger trees. Many planters first contracted workers (or earlier in the period, used slaves) to completely clear the forest, and then planted cacao, usually under a temporary canopy of bananas. Some rigorously cut back native trees as they tended to invade the plantation. Other planters allowed the regrowth of the native trees. In other cases, planters began by only cutting enough of the original forest cover to facilitate the planting of the cacao trees, and allowed the forest to continue to grow as the cacao trees matured and gave fruit over a period of decades. The plantations where a significant portion of the forest was left in place or allowed to regrow came to be called *cabruca* cacao systems (Figure 5.6). People outside the region often simply call it shade-grown, as they do with similar systems for coffee, as described above.

Beginning at least as early as the last years of the 19th century, when most of the region was yet to be cleared, planters argued over the advisability of *cabruca*. Those who tended to consider themselves more educated, 'advanced' and 'scientific' argued that *cabruca* meant low productivity because sunlight, nutrients and water were captured by the trees shading the cacao. Some argued that it promoted pests and disease. On the other side of the argument, planters who preferred shade-grown plantations maintained that it was cheaper and that the cacao trees actually benefited from the shade of the other trees and probably benefited in other ways that they could not explain. In any case, they claimed, production was nearly as high as or even higher than in clear-cut plantations, and costs were lower.

One of the most influential enemies of *cabruca* was a Dutch agronomist, Leo Zehntner, with experience in the cacao plantations of Dutch East India (now Indonesia). He was hired to head an experiment station – which on arrival he lamented was nothing more than the caricature of such an institution – and to undertake a two-year research project on the state of cacao agriculture. For the most part, his report is a model of serious observation and critical analysis. He was shocked by the low levels of education and sanitation in the region and the lack of public spirit among the planters. He was scandalized by pervasive violence and the general treatment of workers (which surely was not much better in the Dutch East Indies) and by the state of the roads and harbour facilities.

Zehntner's criticism of the so-called 'routine' or 'empirical' methods (terms used throughout Latin America at the time to describe agricultural techniques that were considered to be established practices, unaided by 'scientific' advice) of those farmers practising *cabruca* went along the standard lines: cacao would do best where the plantation was clean and



(a)



(b)

Figure 5.6 *The cabruca cacao system in southern Bahia: (a) A view from afar makes it impossible to distinguish between a cabruca cacao and a natural forest; b) a farmer in a cabruca cacao farm*

Source: Angus Wright

orderly and where competing vegetation did not rob cacao trees of light, water and nutrients. This appeared to be self-evident to him, despite the fact that his yield comparisons of *cabruca* and non-*cabruca* were inconclusive. Zehntner believed that *cabruca* resulted at least partly from what he saw as the general evil of Brazil's cacao economy, the predominance of relatively large-scale landholdings often in the hands of absentee or lackadaisical owners and/or managers. *Cabruca*, in this perspective, was simply one aspect of the social backwardness, or, as it was sometimes put, the decadence of the region. The credibility given to his opposition to *cabruca* was probably due more to the way it seemed to represent order and modernity than to its inherent logic. This perspective persisted among many planters, agronomists, cacao export firms and others through most of the 20th century in the cacao region. It has only begun to wither since about 1990 under the force of dramatic events that have redefined the debate. Many still vigorously defend Zehntner's perspective in its 21st-century version, that adds the desirability of chemical fertilizers and pesticides applied to selected varieties grown in 'clean' plantings.

Other trained observers, including the Ukrainian agronomist Gregorio Bondar, disputed Zehntner's findings at least as early as the post-World War I years and continued to do so into the 1930s. They argued that the cacao tree benefited from conditions that resembled the circumstances of the wild forest in which cacao had evolved. They produced statistical analyses, which while suffering from small sample sizes and vaguely defined parameters, seemed to demonstrate equal or superior yields and lower costs on the *cabruca* plantations.²⁵

Later, we will see that the question of the viability and desirability of *cabruca* would have enormous implications on the fate of the native organisms of the cacao-growing region. These implications were not part of the debate over how cacao was to be grown until the last two decades of the 20th century. But to really understand how these implications would eventually play out, we will have to journey through a bit of the history of the region in the 20th century.

Brazilian cacao in world markets: the 20th century

Bondar and others who shared his views were as critical as Zehntner of the tendency toward absentee and inadequate management of the plantations. With price collapses during some years in the 1920s there also began to be increasing criticism of the nearly total domination of regional agriculture by cacao, a classic monocrop that left the region's fortunes totally dependent on volatile international markets for a single luxury crop with dramatic price elasticity. Price elasticity, the tendency of prices to be highly responsive to relatively minor changes in demand, is characteristic of luxury products in general and of such products as cacao, coffee and bananas in particular. If peoples' incomes fall, luxuries

are the first thing to go. Tropical luxury products depend on mass markets among people with marginal incomes, as well as those in more comfortable circumstances, and the tropical agricultural luxuries are in chronic oversupply. In addition, Bahian cacao was of relatively low quality due to a combination of the variety that grew most successfully in Bahia and poor management, processing and shipping practices. For example, it was known for its 'ham fat' smell because *fazendeiros* provided inadequate housing for workers, and so workers often lived and cooked their cheap cuts of meat under the cacao drying racks. It was also often contaminated with salt because the port city of Ilhéus had lost its harbour to silting up, due to the deforestation of clear-cut cacao plantations. The cacao had to be loaded onto freighters from 'lighters' (small barge-like boats), as they pitched and rolled in the open sea, with sacks of cacao beans taking on more than a sprinkling of salt. Bahian cacao thus suffered not only from market volatility but also from quality competition with better varieties grown under more careful management, usually on much smaller landholdings, in other regions of Latin America, Africa and Asia. In general, smallholders, such as the Ashanti of Ghana, grew and processed their product with great care because the owners of the small farms were among the families who actually did the work, and the ability of the farm family to gain the maximum price determined whether the family prospered or starved. Holders of larger plantations in Brazil did little or none of the work, were often absent and had sufficient income from cacao, combined with income from a variety of other investments, to prosper by emphasizing quantity rather than quality as a production strategy. Its quality deficiencies made Bahian cacao especially susceptible to market fluctuations.

The onset of the Great Depression beginning in 1929 sent tropical luxury products and the regions that produced them into a sharp and disastrous nosedive. In Brazil, coffee and cacao beans in some years were so unsuccessful on the market that they were used to fuel steam locomotives. The economic crisis brought a reform-minded revolutionary regime to power in Brazil, as it did in much of the rest of Latin America. The new government was deeply hostile to the traditional domination of the Brazilian government by coffee planters and exporters and their allies among sugar, cacao and other traditional landholding families. As a consequence, in the cacao region, the reformist Vargas regime created the Institute of Cacao, meant to resolve many of the region's problems. The most important function of the Institute of Cacao was as a marketing cooperative designed to gain better prices for Bahian cacao. However, the Institute carried forward a more general reform agenda. It planned to diversify regional production, improve technical research and extension, improve roads and bridges, tackle regional public health problems, and improve public education. The Institute nourished an undercurrent of criticism of regional domination by an alliance of foreign export houses with a faction of wealthy local planters, and promised a vaguely defined

renewal and democratization of local life and institutions. Conditions in most of these areas were so bad that almost any action at all would have constituted progress. The landholders and exporters who had controlled the region saw little reason for public investment, and some even feared that improved social conditions would threaten their ability to hold wages down, resist challenges to their often fraudulent claims to land, and maintain political dominance. However, in the severe economic crisis of the 1930s, as a group they were so weakened politically that they could not mount successful opposition to reform and were willing to grasp at nearly any straw that might bring them economic relief. The Vargas regime provided a sweetener in the form of a debt forgiveness programme for planters that overcame, for the time, any determined resistance. At least some of the powerful planters were willing to believe in the benefits of a marketing cooperative.

The story of the Institute and its partial successes and eventual destruction (which for all practical purposes occurred in 1942) is intriguing and complex.²⁶ With respect to *cabruca* cacao and biodiversity, however, the Institute's influence boils down to a rather simple matter. Endowed with a comprehensive reform agenda and associated with aggressive young politicians and public officials, the Institute came to represent a broad challenge to the regional power structure composed of conservative large landholders and export firms. Once the price of cacao rose again, partly due to the success of the Institute's cooperative, the conservative alliance was able to regain the economic strength it needed to launch a challenge to the Institute. The challenge was successful, and the groups that managed to restore their authority in the region came to a firm conclusion: no one should be allowed ever again to put forward an agenda of social reform in the region under the guise of aiding the recovery of the region's economy. Thus, when planters emerged from the glory days of high prices for cacao in the years immediately after World War II into a new overproduction crisis in the 1950s, they were determined that any proposed solutions be strictly technical with no aroma of social reform or unorthodox thinking.

The technification of cacao

In this technocratic state of mind, a new institution was created, *Comissão Executiva do Plano da Lavoura Cacaueira* (CEPLAC), financed by a direct tax on each sack of cacao exported from Brazil. This institution was not to get involved in cooperatives, social reform or diversification of regional production. Its purpose, stripped of a certain amount of flowery rhetoric, was simple: to discover how to increase the yields of cacao such that Brazilian planters could out-compete cacao growers in the rest of the world. They were told by agricultural scientists that this could be done by the same kind of intensification that was occurring in the development of Green Revolution grain crops. As a consequence, as we shall see, the conservative alliance of planters and exporters, through CEPLAC, ended

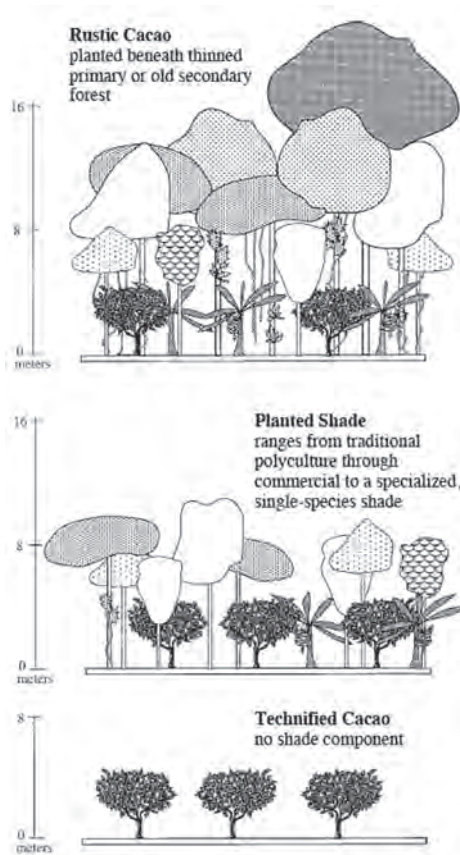


Figure 5.7 *The range of cacao systems extant in the world*

Note: In southern Bahia it is possible to find all three systems and some intermediate ones. Studies have shown that with management intensification there is a loss of biodiversity (Rice and Greenberg, 2000).

Source: Modified from Rice and Greenberg (2000)

up mounting a major attack on shade-grown cacao as a technique while introducing a new kind of cacao agriculture that would represent a far more aggressive threat to biodiversity than even the older clear-cutting techniques as advocated by Leo Zehntner and other agronomists (Figure 5.7).

CEPLAC agronomists and other agricultural technicians selected and bred cacao varieties with higher yields than older varieties. These varieties proved their worth when heavily fertilized. They tended to be more pest-vulnerable and were thus dependent on synthetic chemical pesticides. And, CEPLAC specialists insisted, they would thrive only if competing vegetation and trees were rigorously eliminated, with

exceptions under some circumstances for bananas and other temporary plantings to shade immature cacao trees. A powerful public propaganda and private advertising accompanied the programme, associating *cabruca* with ignorance, neglect and decadence. New stores in the region opened up to sell farm chemicals and machinery and were seen as a sure sign of economic progress. Once the basic research for the programme was accomplished and its techniques took root in the shallow forest soils of the region, yields on the *fazendas* using the new package did indeed increase spectacularly. Regional production roughly tripled from the late 1960s to the mid-1980s.

As has happened so frequently in the history of technological developments in agriculture, the production increases were a disaster for the region and for cacao growers around the world. Many new areas of cacao agriculture had entered the market during the period, and some other major producing countries – notably, Côte d'Ivoire – had pursued the same kind of research and technical programme as CEPLAC in Bahia. The global cacao glut led to a reduction of two-thirds and more in international prices in a few years. By 1990 southern Bahian cacao growers, whatever production techniques they were using, were facing ruin or had already given up farming in the region. The production package of new varieties, chemical fertilizers and pesticides was nearly universally abandoned because the expense was impossible to recuperate in the depressed market. By default, plantations not in *cabruca* and not converted to cattle ranching or sugar cane were in general tending back towards something more like it as vegetation moved in. The final blow to the regional cacao economy was the appearance in 1989 of a fungal disease of cacao, witchbroom disease, or *vassoura de bruxa*. The disease was common in most cacao-growing regions of the world, but one advantage that Bahia had previously enjoyed was its absence in the *Mata Atlântica* region.

The conservation agenda faces the reality of land tenure

Ironically, it was just as the cacao economy was entering extreme crisis that conservationists began to appreciate the value of *cabruca* cacao plantations for the preservation of biodiversity. The International Union for Conservation of Nature (IUCN) had designated the region as a 'hotspot' for biodiversity conservation in 1988²⁷ and the WWF was investing money in the establishment of the Una Biological Reserve in the region. Conservationists were concerned about the broad range of species diversity in the region, but their campaign focused on the need to preserve the golden-headed lion tamarin, a small, endangered monkey species. Tamarins of several species were well known in Brazil. As cute, intelligent and highly active primates, they held the kind of broad public appeal that helps conservationists raise money and gain public support and understanding of conservation needs. Golden-headed lion tamarins were

thought to number no more than a few hundred, with the population concentrated in the cacao region. It was thought that the population owed its existence to the survival of relatively small stands of more or less undisturbed forest in southern Bahia. A young Brazilian biologist, Cristina Alves, wrote her Master's thesis at the University of Florida on the conservation of the golden-headed lion tamarin, showing that *cabruca* cacao was surprisingly effective as habitat and as a high-quality matrix between wild habitats.²⁸ In subsequent years, other researchers further validated her findings and were able to locate a much larger number of the monkeys in shade-grown cacao stands than had been imagined. It did not require much more thought for conservationists to realize, and begin to demonstrate, that what was true for the tamarin was true for a broad range of other plant and animal species.²⁹

This was of added importance because the difficulties of buying and protecting wild forest remnants were becoming ever more evident to the conservation organizations. Although the WWF had purchased 12,000 hectares of forest, this was at best a small parcel on which to base the survival of the golden-headed lion tamarin and other endemic species. Also, WWF was discovering that in southern Bahia, even more than in other regions around the world with similar problems, the purchase of land did not translate into being able to control what happened on it. First, land titles in the region were based on a system of property law that was shot through with legal contradictions, and that had been enforced, or unenforced, through political means that constituted pervasive fraud. The most popular Brazilian terms for land fraud were coined in the region. For example, the term *grilagem*, used generally for a variety of forms of chicanery in establishing landownership, originated during the land rush in the cacao zone in the 19th century. It came from the word *grilo* (cricket) because the ancient character of land documents was commonly faked by enclosing newly forged documents for weeks or months in a box with crickets, which ate holes in the paper and yellowed it with waste products. Fraud was so common and establishment of legitimate land title rare enough in the region that little credibility was given to claims of ownership that could not otherwise be enforced than through influence-peddling and/or violence. When the WWF became aware of the likelihood that people who claimed to hold title to land in the area they were buying did not have clearly defensible legal title, they faced a difficult dilemma. How could they obtain the best claim to ownership when there were competing claims, and how could they deal with the counter-claimants? Privately, they told us that the solution adopted was one that had come from local advisers. Namely, the technique adopted was to cut through the often insurmountable difficulties of finding out who constituted the unique and legitimate owner of a given piece of land. This was done by promising to compensate the claimants who held the most political and economic power in the area on the condition that these claimants would receive the compensation only when they had physically removed the

less powerful counter-claimants. It was understood that they might do this through their influence over local police and/or through hiring from the large pool of gun-thugs who thrive in the region. The poorer counter-claimants were usually families or small groups of families who had established livelihoods in the forest and who usually based their title on the ancient and honourable Portuguese and Brazilian tradition of ownership as derived from effective use of the land – that is, the legitimate owner was the person who was giving ‘social value’ to the land by putting it to an economic use. Some of the counter-claimants had their own documents to pose against those of others. The WWF found, as is typical in many areas of Brazil, that the same piece of land might have multiple claimants to ownership, each with his or her own documentation and/or legally arguable rationale.

The dilemma created by the inability to discover who had the most legitimate claim to ownership is common. It is easy to understand why conservation organizations adopt rough-and-ready solutions to such difficulties, essentially because the legal system cannot be expected to provide a more just remedy. As understandable as the dilemma may be, the kind of tactic used in southern Bahia inevitably brings about a series of other very serious problems.

First, those removed from the area are human beings with their legitimate rights to livelihood and dignity, whatever the fine points of the legality in a profoundly flawed and corrupt legal system. Removal may mean that the families will be unable to find any other means of survival. This may lead to extreme deprivation, including malnutrition, disease or starvation. Second, the families removed, and countless others in similarly difficult circumstances, will have powerful incentives to re-enter the area to poach or to attempt to re-establish residency. This poses a danger of further conflict and of continued threats to the forest and wildlife. Third, with the loss of the families who had been managing to live in a largely forested and species-rich environment, conservation organizations were likely to lose complex bodies of knowledge about how people were able to make a living within a substantially forested landscape. Fourth, the more powerful claimants who have been compensated sometimes remove valuable timber, or contract poachers either before they turn over ownership to the conservation organization or on an ongoing basis later. Since they are in effective control of the law in the area, this is easier and more likely than it might appear. Fifth, because of these problems and others, the conservation organizations and government agencies set up with the task of protecting the area will almost certainly suffer from a legitimacy problem in the region because what they have done continues to be based on the endemic contradictions, absurdities and injustices with which people are all-too-familiar. The sense of support for the conservation projects (that virtually all experience shows is critical to successful protection of landscapes and species) will be weak or missing altogether. Many local people will be positively hostile to conservation. WWF and

government officials privately admit to the persistence of such problems and to the partial control they have over the reserves established. Attempts to protect the forest remnants in southern Bahia have not been completely defeated, but they have been badly compromised.

With small reserves themselves lacking the full protection they need, the quality of the mosaic in and around the forest is of immense importance. This is where *cabruca* cacao became a vital potential partner in conservation efforts. For reasons that are not altogether clear, there had been substantial resistance to CEPLAC's attempt to eliminate *cabruca*. The most important reason for the survival of the *cabruca* was almost certainly that it was the lowest-cost way to produce cacao. This was attractive to owners of smaller operations with little capital, and to some holders of large plantations who had multiple economic interests and regarded their holdings as a cash cow but who had little interest in sinking money or management effort into their cacao farms. There has always been, in addition, a solid core of planters, large and small, who believed, and continue to believe, that *cabruca* produce more cacao on average over the years. They also assert that in those years when production is low, the compensation of low costs makes up for yield losses. When CEPLAC's clear-cut, chemical-dependent cacao was made impractical by low cacao prices, *cabruca* might have a better chance of gaining ground as a low-cost alternative. With additional research and financial support from conservation organizations, growing cacao in the shade of the forest might become yet more attractive. The great problem, however, is that cacao prices fell so low that few planters wanted to stay in cacao farming at all. The main alternatives in the very delicate soils that predominate in the region – a shallow layer of soil made up mostly of rapidly decomposing organic matter laid over sand or heavily mineralized thick clay – have been cattle ranching and sugar cane, both of which tend to be short-lived and highly destructive strategies (Figure 5.8). Ranching, sugar cane and other cropping alternatives are so destructive of the soils that they are capable of greatly retarding forest regrowth for a long time to come even if agriculture were subsequently to be abandoned altogether. The combination of soaring petroleum prices and a flourishing Brazilian programme producing the world's largest quantity of ethanol-based transportation fuels makes it particularly dangerous for sugar cane to become the most attractive expedient for local landowners.

All of this has been complicated by other factors. One is the weakness of the government's environmental enforcement agencies. While we were doing research in the area in March 1992, established logging mills were busy and three new sawmills opened during a time when officially all logging of primary forest was absolutely prohibited, and limited logging of secondary forest and *cabruca* stands required special permits, none of which had been issued and which would not be issued for months or even years after application. Local conservationists feared for their lives if they were seen to be documenting the logging. During the same month, the international renowned head of Brazil's environmental ministry, Jose



Figure 5.8 *Recently converted cattle pasture in the cacao-growing region of southern Bahia, Brazil*

Note: This farm used to be planted with cacao but because of the low price and the introduction of the witchbroom disease, it was converted to a cattle ranch.

Source: Angus Wright

Lutzenberger, resigned in a highly public gesture meant to express his complete frustration with his job, declaring the ministry to be 'nothing more than a den of thieves' and a 'one-hundred per cent owned subsidiary of international timber firms'. Logging firms operated in southern Bahia, as in most of Brazil, with complete impunity from the law. With cacao *fazendeiros* desperate for income, the logging of *cabruca* cacao stands and all other forested areas would speed up dramatically, even where no agriculture at all replaced them.

The conservation agenda faces a cry for social justice

Another complicating factor was the rise in Brazil and in southern Bahia of organizations of rural people pressing for land reform. These included traditional unions of rural workers enjoying something of a renaissance in the wake of Brazil's return to civilian rule, and, most importantly, the MST, a new, militant, aggressive land reform movement. A Roman Catholic organization, the *Comissão Pastoral da Terra* (Pastoral Land Commission) provided documentation and support for these organizations as they fought for access to land for the poor. During the late 1980s, these groups began to organize land occupations of poor families to claim land under

the complicated provisions of Brazilian land law. The law allowed property claims by people who put land to use, even where those properties had been deeded to others who demonstrably were making use of the land.³⁰ Brazilian law also mandated a land reform that had never been seriously implemented. For the MST and some of the other organizations, their land occupations were meant not simply as an end in themselves, but also as a way of pressuring the government to undertake land reform as an aggressive, serious national policy, and to adopt other measures to improve the lives of the poor. We have written elsewhere on the complexities of Brazilian land law and land reform,³¹ much of which, while fascinating, is beyond the scope of this book.

In southern Bahia, as throughout Brazil, individuals and small groups had long occupied land in the hope of getting either temporary or permanent use of it, and perhaps, an ownership claim. Where land was of good quality, they would often be subsequently run off the land by more powerful people through legal manipulation, intimidation and/or violence. What had changed by the 1980s was that the MST and others had begun more effectively to organize occupations and gain support for them, making it difficult to dislodge the occupiers. They were also succeeding to a significant degree in gaining the support of urban and rural people all over Brazil for a serious land reform. They were and are active in many regions of Brazil, and, with more than a million members, the MST is considered to be one of the largest social movements in the world (Figure 5.9).

Land occupations in southern Bahia took place in cacao plantations and in secondary or primary forest,³² sometimes resulting in the deforestation of substantial tracts. It was just as the rhythm of occupations began to increase significantly that the bottom fell out of the cacao market, witchbroom disease arrived and conservationists who had begun to work more seriously to preserve biodiversity in the region started to understand the value of *cabruca* cacao for conservation purposes. The convergence of all these elements raised a variety of complicated and difficult questions for all involved.

Was it possible to protect or promote *cabruca* stands at a time of such low cacao prices, and with the additional problem of a rampant disease outbreak? If not, what would replace *cabruca* and what would the consequences be for biodiversity conservation? Did the poor people occupying land represent a threat to the forest, *cabruca* and biodiversity, or could they play a positive role in conservation? With cacao agriculture in severe crisis, how would those who occupied land and land reform beneficiaries make a living from the land without further degradation of the soils and forests of the region? There are still no definitive answers to these questions. However, one idea is for there to be a more thorough, ongoing documentation of the positive role that shade-grown cacao can play in biodiversity conservation. As a consequence, international and local conservation groups have sought ways to promote *cabruca* stands.



Figure 5.9 A march of 18,000 militants of the Landless Workers Movement (MST) in Brazil during its 5th Congress in 2007

Source: Wilson Dias (licensed under the Creative Commons License Attribution 2.5; Brazil, http://commons.wikimedia.org/wiki/File:MST_06142007.jpg)

In addition, the MST and other organizations of rural people have sought to use *cabruca* as part of a more comprehensive strategy of building rural livelihoods, as well as a way of gaining public sympathy and support. These organizations and the communities affiliated with them have done a great deal of experimentation of their own and have sought professional technical advice on how to transform *cabruca* into a more complex, stable and profitable activity. Unfortunately, most agronomists and other professionals are poorly trained to be able to offer much help beyond recommending what seems to be the obvious. The main method for doing so is diversification of economic crops within the forest stands, incorporating such crops as piassava (a palm that, when properly farmed, can produce a large and continuous crop of high-value fibre used for brooms, brushes and durable and attractive thatch roofs), citrus, cinnamon, black pepper, pineapple, *caju* (cashew, valued in Brazil for its fruit as well as the cashew nut), mango, banana and other trees and perennial crops. The more conceptually sophisticated (though not necessarily the best or most productive) of these efforts focus on the use of a diverse combination of largely perennial plants, some of them producing an economic product, some not, to mimic the structure and ecological functions of the indigenous forest plants.

In addition, it has been shown that witchbroom disease can be controlled reasonably well with careful trimming and destruction of the shoots produced by the disease. While many wealthier planters consider this too expensive and troublesome, the communities of smallholders in land reform units, with strong self-interest and motivation, can provide the careful observation and labour needed if they are convinced the labour is worth their while.

Some planters and communities have found fish and shrimp aquaculture to be a good complement to forest-based production, making it possible to increase income while maintaining forest and *cabruca* stands that help to maintain water quality and stabilize drainage, reducing the dangers of droughts and floods to aquaculture ponds, as well as to other crops and to homes. Planters and a few communities have earned further supplemental income through tourism, variously termed agro-tourism, eco-tourism, adventure tourism or just plain tourism. The very high rainfall and the endemic poverty and violence of the region tend to discourage tourists. However, the beauty of the hills and low mountains when substantially covered by forest and *cabruca*, the countless spectacular flowering plants and the magnificent and seemingly unending beaches guarantee a certain modest flow of tourists to the region. Even the region's reputation as a kind of Brazilian Wild West, both excoriated and celebrated in the tens of millions of copies of Jorge Amado's novels in all of the world's major languages (a phenomenon much like that of Amado's imitator and friend, John Steinbeck, in Monterey, California), provides a stimulus to tourism.

In his older and more mellow years, Amado wrote of the region as a vast and beautiful cultivated garden. It certainly has the potential to be just that, incorporating both the preservation of a great array of wild species and reasonably prosperous livelihoods. Some *cabruca* cacao plantations and smallholder land-reform communities epitomize the possibilities. But the somewhat misty and sentimental vision of Amado's later years is very far from realization, and to the extent that it does exist, may be disastrously undermined in the future. Perhaps the most dangerous element is on the one hand, the failure to realize the region's enormous potential for a relatively harmonious balance between conservation and livelihood in a species-rich tropical forest environment, and on the other hand, the possibility of a steady slide into further extreme poverty and environmental destruction.

THE PRODUCTION OF FOOD AND THE BIODIVERSITY CONNECTION

Both coffee and cacao are excellent examples of agro-ecosystems that can and do contain much biodiversity and form high-quality matrices. Furthermore, in many cases, especially in small landholdings, these systems contain many other species that contribute to the livelihood of rural

families (other commercial crops, food, medicinal plants, ornamentals, honey, etc.).³³ For example, in 2008 we visited a 'coffee' farmer in the state of Kerala in India. His farm was one and a half hectares and his main crop was coffee, which he sold in the nearby town. However, in this small farm he also cultivated cardamom, vanilla, pepper, citrus of various kinds, bananas, coconuts, mangos and a variety of other minor crops and fruit trees that were either sold locally or consumed by the family. In addition to the crops and trees, he had a few goats and a cow that provided fresh milk and cheese, and manure to fertilize his organic farm. According to him and other locals, it is not uncommon, especially for small-scale producers of coffee and cacao, to cultivate and promote many other species (either for their exchange or their use value) beside the main crop, a pattern we have seen elsewhere in the production of both coffee and cacao.

However, an argument in favour of the importance of the agricultural matrix for biodiversity conservation cannot be made based solely on these two cash crops. Coffee and cacao have become iconic crops for the idea of wildlife-friendly agriculture, but people need to eat and, unfortunately, most of the food that we consume does not come from these highly diverse agroforestry systems. The vast majority of the calories we consume come from just four or five plant species: maize, wheat, rice, soybeans and cassava. None of these essential calorie factories can be grown in shaded conditions, so the sort of analysis of matrix quality so evident in the case of coffee and cacao may not apply in the case of these food crops. Indeed, one of the main victims of the industrialization of agriculture was diversity, the diversity of plants, animals and fungi that we consume. Throughout human history, thousands of organisms have been regularly consumed. Even after agriculture became the main source of sustenance for the majority of human beings, the variety of crops and their genetic diversity remained astonishing. The industrialization of agriculture put an end to this vast diversity. Although visiting a supermarket in any big city today suggests that we have a wide selection of food products to choose from and that globalization has broadened our choices of foods, the reality is that the hundreds of different kinds of breakfast cereal, for example, are made mostly from maize or wheat, just two agricultural crops. According to the Food and Agriculture Organization of the UN (FAO), the world has lost 75 per cent of its food diversity over the last century. Indeed, today 95 per cent of the calories consumed by humans come from just 30 plant varieties.³⁴ Not only have we lost the diversity of types of plants and animals that are cultivated and reared, but also, within these main crops, we have lost the genetic diversity.

One of the main reasons for the decline in crop diversity has been the drive towards mechanization, and the consequent dependence on monocultures to facilitate the use of machines – all part of the historical, economic and political roots of agricultural transformation. Later, in the 1960s, the Green Revolution, with its technological package that included high-yielding varieties (HYVs), pesticides, fertilizers and irrigation technology,

contributed further to the homogenization of rural landscapes. In this section we examine how food crops also relate to our main themes of how agriculture affects biodiversity conservation. We first focus on the rice agro-ecosystem as an important repository of biodiversity and second on maize and its traditional production system, with important lessons about how agro-ecosystems create landscape mosaics and thus promote high-quality matrices in fragmented landscapes. In both cases we will conclude that small-scale grain farmers, who in some regions still produce a large amount of the food consumed in the contemporary world, play a crucial role in directly maintaining biodiversity and in the indirect construction of a diverse landscape mosaic, which, we argue, is essential for long-term conservation in a fragmented landscape.

Rice production and biodiversity

Rice cultivation is the main productive activity and source of income for about 100 million people in Asia and roughly the same number in Africa. Furthermore, rice is often the main source of employment, income and nutrition for many of the world's poorest people in the most food-insecure areas of the world. Nearly 2.5 billion people depend on rice as their main food, and hundreds of millions of people spend more than half of their incomes on rice to feed their families.³⁵ In the context of neo-liberal globalization, rice has followed a similar but distinct trend to maize (discussed later). Subsidies and technical improvements, mostly in developed countries, but also in some developing countries, have increased rice production, lowering production costs and resulting in overproduction and a predictable drop in price. The price plunge in the late 1990s had a significant impact on small-scale farmers by plunging them further into poverty, undermining household food security, and encouraging rural to urban migration.³⁶ The result has been an increase in the size and levels of intensification of rice production systems and the displacement of small-scale rice farmers. Given the direct connection between rice markets and rural livelihoods, rice is a perfect subject with which to explore the interconnectedness of biodiversity, agriculture and food sovereignty.

Wetland rice ecology and biodiversity

Rice cultivation covers from 130 to 150 million hectares worldwide, 89 per cent of them in Asia. In the Western Hemisphere, the US and Brazil produce more than two-thirds of the rice. Although some rice is cultivated in upland areas and with no surface or rhizosphere water accumulation (the so-called upland rice), these systems represent only about 10 per cent of all rice production.³⁷ The following discussion pertains only to the water-flooded system.

As we have noted many times previously, one of the main principles of biodiversity conservation in agro-ecosystems is that the agro-ecosystem

should resemble the natural ecosystems in the region as much as possible. In that sense, it is significant that flooded rice systems have been defined as agronomically managed marshes or a type of freshwater wetland with a cultivated grass. Most flooded rice fields are indeed connected to natural wetlands and share many organisms with these natural ecosystems. It is precisely because of the presence of water in wetland rice that this agro-ecosystem is an important habitat for a wide variety of aquatic and terrestrial organisms. Rice paddies, along with the adjacent natural wetlands, frequently compose a mosaic of habitats that harbour a rich diversity of flora and fauna. According to ecologists who have studied these biologically rich mosaics, biodiversity is maintained by rapid colonization as well as rapid reproduction and growth of organisms. Although several studies dating back to the 1940s and 1950s have documented the biological richness of the aquatic phase of rice production, few comprehensive studies exist on the ecology and diversity of the rice fields.³⁸ A survey of an irrigated rice field ecosystem in Sri Lanka documented 494 species of invertebrates, mostly arthropods, belonging to 10 phyla, 103 species of vertebrates, 89 species of macrophytes, 39 genera of microphytes and 3 species of macrofungi.³⁹

Natural wetlands are critical habitats for the survival of many species of both terrestrial and aquatic organisms. However, these ecosystems are suffering a rapid decline in many areas of the world. As a managed wetland, rice agriculture serves as an important habitat refuge for those wetland-dependent species, and as such, is beginning to receive more attention from the conservation community.

The biodiversity of rice fields can be divided into aquatic invertebrates, terrestrial invertebrates, vertebrates and plants. Here we summarize results from many studies that have examined biodiversity in rice fields.⁴⁰

Aquatic invertebrates inhabiting rice fields include surface water-dwelling insects, zooplankton (protozoans, micro-crustaceans, rotifers and others), aquatic insects and their larvae, and benthic organisms (bottom-dwelling), such as nematodes, molluscs and annelid worms. In other words, aquatic organisms in rice fields cover the entire spectrum of freshwater fauna. Of these, the benthic fauna is the most diverse, comprising almost 40 per cent of the species of aquatic invertebrates. Population density of rice field benthic fauna is also high compared to natural and artificial ponds. Freshwater crabs are a common component of the benthic fauna and are important as scavengers and as food for other animals in the ecosystem. Zooplankton is the most studied group in rice fields, where they tend to be as diverse as in ponds, and more diverse than in rivers, streams and river floodplains. Aquatic insects are also very diverse in the rice fields. Unfortunately, among the most diverse and abundant of the aquatic insects are mosquitoes. Worldwide, 137 species have been listed as breeding in rice fields. Due to human health implications, mosquitoes have received the bulk of the attention from researchers. Few studies have documented other aquatic insects in rice fields, among them

a study that listed 117 species of aquatic beetles in rice fields worldwide. Interestingly, almost all of the aquatic insects in the most abundant groups (beetles, bugs and dragonflies) are predators, including predators of mosquitoes.⁴¹

Terrestrial arthropods are also a very diverse component of the rice fauna. One study in Sri Lanka listed 280 species of insects and 60 species of spiders and their relatives for an astonishing total of 340 arthropods in one rice field ecosystem. Several studies have examined the succession of species with the growing cycle, and most of these have examined the trophic interactions, with some constructing food webs of the terrestrial invertebrates. Due to the importance of rice as a food crop, most of the studies of terrestrial arthropod diversity separate the arthropods into herbivores (potential pests) and natural enemies. In this respect, the study from Sri Lanka is illustrative. In this study, the majority of insects belonged to two orders: the Hymenoptera (81 species of wasps and ants), most of which are parasites and predators of other insects, and the Lepidoptera (58 species of moths and butterflies), all of which are herbivores. When combined with the spiders, the natural enemies accounted for at least 41 per cent of the terrestrial arthropod species diversity in these rice field ecosystems. Herbivorous insects represented 38 per cent of the diversity, with many of them (almost 60 per cent) being visitors or spillovers from weedy and other surrounding vegetation. It has been argued that the long history of rice cultivation in many parts of the world has allowed stable relationships to evolve between rice pests and their natural enemies. Whether this is true or not is hard to tell with short-term studies. Nevertheless, it is evident that in most instances, and in particular when no insecticides are used and there is a high level of landscape heterogeneity, the richness and abundance of natural enemies is greater than that of rice pests.⁴²

A wide spectrum of vertebrates belonging to all major groups is found in the rice fields. In particular, the rice ecosystem is an important feeding area for aquatic birds. The wetland rice ecosystem acts as a temporary artificial wetland with alternating flooding and dry periods, and usually contains a spatial and temporal heterogeneity that facilitates the establishment of large bird populations. Waterfowl, shore birds and wading birds utilize rice fields to the greatest extent. The rice ecosystem also harbours species under threat of extinction, like the Bengal florican in Cambodia, an endangered bird species with only two populations remaining.⁴³ In the last few years, due to the decline in natural wetlands, there has been an increased interest in the potential of rice fields for the conservation of waterbirds. In the western hemisphere, the Rice and Waterbirds Working Group was formed to promote conservation of waterbirds using habitats associated with rice cultivation. The group has an interesting mix of participants that include researchers from universities, NGOs and national museums in Costa Rica, Brazil, Argentina, Cuba, Canada and the US, and the Fish and Wildlife Service of the US. It has obtained funds from

Monsanto, the giant seed and agrochemical company that is one of the major players in the production of transgenic seeds. Monsanto's interest in this initiative could stem from the potential of Bt rice – a genetically modified strain that could reduce the amount of insecticides used in rice, at least temporarily – or the potential of a Roundup Ready rice, which, according to its proponents, could substitute for more toxic herbicides.⁴⁴ Whatever their interest, the potential use of transgenic rice in conservation programmes is mired in controversy, and the potential impacts on the environment should be carefully examined before these varieties are released, especially in the centres of origin of rice. The role and interest of Monsanto apart, the goals of the working group include engaging in a dialogue with the rice industry and developing management and policy recommendations to optimize bird–rice relationships. They are also beginning to explore best practices and biodiversity certification schemes similar to those developed for shaded coffee.

Fish are another integral component of the rice field vertebrate fauna. Although some authors consider the rice field agro-ecosystems as essentially an extension of the natural local wetlands that should reflect the diversity of these habitats, a study in the Muda rice irrigation system in Malaysia reported lower fish species-richness in the rice fields than in the natural marshlands. This study listed 39 fish species occurring in the rice fields. Fish living in the rice fields can also provide an important service to the rice ecosystem. Some fish specialize on mosquito larvae and can be important biological control agents of these vectors of human disease. Likewise, fish that feed on snails may control the vector of schistosomiasis, or may be control agents of the apple snail, a pest of rice.⁴⁵

Rice fields are also important habitats for amphibian and reptiles, many of which are insectivores and implicated in the important ecosystem service of pest control. The study from Sri Lanka mentioned earlier reported 21 species of reptiles and 18 species of amphibians. However, this fauna has not been very well studied in rice fields. In Cambodia, an endangered species of caecilian (a worm-like amphibian, *Ichthyophis bannanicus*) lives in the rice fields. This species is used for medicinal purposes, and some argue that its medicinal value may lead to the controlled cultivation of the species in the rice fields, ultimately saving it from extinction.⁴⁶ Amphibians in particular are an important group to study since, with the decline of wetlands, rice fields could be important breeding grounds for them. However, amphibians are also extremely sensitive to agrochemicals in the water, so increases in pesticide use in rice fields are not likely to be sanguine for this group. To this effect, the introduction of herbicide-resistant (Roundup Ready) rice could have a particularly devastating effect on amphibians since Roundup, the commercial formulation of glyphosate, to which the herbicide-resistant crops are resistant, has been shown to be fatal to tadpoles at the recommended application levels.⁴⁷

Many of the mammals that inhabit rice fields are considered pests because they eat rice and also carry human pathogens either directly or

via vectors like ticks and fleas. Insectivorous mammals, like shrews and bats, on the other hand, can be beneficial.

Finally, rice fields are an important habitat for a wide variety of plants and other primary producers. This component of the biodiversity of rice fields can be divided into macrophytes, mostly terrestrial and aquatic plants, and microphytes, mostly algae. More than 1800 weed species are reported in the literature as occurring in rice fields in Asia and Southeast Asia alone. Grasses and sedges are the most common of the plants found in rice fields. A variety of photosynthetic micro-organisms are present in the aquatic sector of rice fields. Some of these are extremely important for nitrogen fixation and for providing nutrients and organic matter to the system.⁴⁸

The above review is intended to show that rice fields are important habitats for wetland biodiversity, especially in areas where natural wetlands have been destroyed and left in a fragmented state. Likewise, and important for the argument of this book, these artificial wetlands can be important temporary habitats for organisms that are migrating from patches of natural wetlands. Unfortunately, conservation biologists have yet to explore the role of rice fields in the metapopulation context – an important research area, in our opinion.

Biodiversity in rice production, and the livelihood of farmers

It comes as no surprise to traditional rice farmers that a rich diversity of aquatic organisms can be found in rice-based agro-ecosystems. They have nurtured and used this biodiversity for generations. Some rice-based ecosystems contain more than 100 useful species that are important resources for human communities, and can offer a reliable safety net that could protect small-scale farmers in the face of crop failure and other food shortages (Figure 5.10). Studies from Cambodia, China, Laos and Vietnam documented a total of 232 aquatic species that are collected and used by rural households in these countries. Fishes, crustaceans (shrimp and crabs), amphibians (frogs, toads and salamanders), reptiles (snakes, lizards and turtles), molluscs (snails), plants and insects supplement the rice diet with important animal protein, fatty acids and other essential micronutrients that are not found in rice (calcium, iron, zinc, vitamin A and limiting amino acids).⁴⁹ In particular, small fish that are eaten whole provide adequate amounts of calcium and vitamin A. The calcium comes from the fish bone, and eating only 50 grams of the small fish harvested from the rice fields is enough to get the recommended daily calcium intake for an adult. Indigenous people in Bangladesh recommend eating the small mola fish, which grows in the rice fields, for curing night blindness – a temporary blindness we now understand is caused by vitamin A deficiency. This is a good example of how local indigenous knowledge frequently has a sound scientific basis, since vitamin A is found in the eyes and viscera of fish (which are ingested when the fish is eaten whole).⁵⁰



Figure 5.10 *Man fishing in a rice field in Vietnam*

Source: unknown

Farmers that culture fish concurrent with rice have found increases in rice yields, especially on poor soils and unfertilized crops. It has been reported that with reduced cost of pesticides (due to biological control with fish) and additional earnings from fish sales, rice/fish farms report a net income that is 7 to 65 per cent higher than that of rice monoculture farms.⁵¹

There is no doubt that the aquatic life found in diverse rice ecosystems provides critically important resources for rural livelihoods, and currently contributes to food security, especially for the rural poor in Asia. These resources are also important as a source of income since some are traded in local markets and some are used for medicine, feed for other animals, bait for fishing, decoration and materials for wrapping food. Ironically, most development plans in rice-growing regions focus on increasing rice yields, mostly through the use of HYVs and the use of agrochemicals, which result in a dramatic reduction of these other aquatic resources and the predictable subsequent deterioration of the nutritional condition of the rural poor.

Loss of biodiversity and the legacy of the Green Revolution's HYVs

Unfortunately, the high associated biodiversity of the traditional rice ecosystems is declining very rapidly. All major fish-farming countries have reported declines in the availability of wild aquatic resources in rice fields. In particular, fish catches from rice fields have diminished considerably. Rice farmers in Xishuangbanna in Yunnan Province, China, claim that the aquatic resources they collect today in one day are equivalent to what

they collected in one hour a decade ago. In Cambodia, farmers estimate that at this rate of decline, in three to five years there will not be enough fish to make a living. Overall, the contribution of rice-based captures to household consumption has declined from one half over a decade ago to less than a third today.⁵²

Increased fishing pressure on aquatic resources is partially to blame for this decline. However, the transformation of the rice-farming system with an emphasis on industrial forms of agriculture is the main culprit for the decline in the abundance and diversity of aquatic resources in the rice ecosystem (Figure 5.11). The history of the rice Green Revolution in Indonesia is illustrative of the short-sightedness of this approach, and can provide good points for reflection about the need for an agro-ecological approach that can conserve wild species and agro-biodiversity and provide a dignified way of life for millions of people in the world.⁵³

As discussed in Chapter 3, the perceived success of a high-yielding wheat variety developed by Norman Borlaug in Mexico led to the spread of the so-called Green Revolution for maize, rice and other crops in the rest of the world. In Asia, the International Rice Research Institute (IRRI), together with national research programmes, promoted development of short-duration high-yielding rice varieties, beginning in the 1960s. As a result of this Green Revolution, Indonesia passed from being the largest rice importer in the world to being self-sufficient in rice in the mid-1980s.⁵⁴ However, as was the case with the Green Revolution in other countries and for other crops, this achievement in yield increases came at a high environmental and human cost, as elaborated on in Chapter 3.

In Indonesia, the government contracted with pesticide companies for the aerial spray of phosphamidon, produced by Ciba Geigy, to control the rice stem borer. This started before the spread of the HYVs in the late 1960s and continued through the 1970s. By 1974, an even more devastating pest, the rice brown planthopper, emerged. This was a classic case of secondary pest outbreak (as discussed in Chapter 3). This pest had not been reported as a pest in rice fields before and emerged as a pest only after massive aerial spraying with broad-spectrum insecticides that eliminated its natural biological control agents. The Indonesian government, rather than reducing pesticide applications to restore the populations of natural enemies in the rice fields, started a programme of insecticide subsidies that made insecticides available to farmers for 20 per cent of the actual cost. By the mid-1980s the cost of the insecticide subsidy plan reached US\$120 million per year. In spite of the massive pesticide applications, or rather because of it, damage caused by the rice brown planthopper continued to increase, becoming so severe that in 1977 alone, the amount of rice lost to the pest was enough to have fed 1.2 million people for a year. That year the IRRI⁵⁵ started to multiply and distribute a seed variety from South Asia that was distasteful to the rice brown planthopper. But within three seasons the planthopper had evolved to readily feed on this variety, and the farmers were back to square one. In the early 1980s, scientists



(a)



(a)

Figure 5.11 (a) *Diverse and (b) homogeneous rice landscapes illustrating the loss of agrobiodiversity in Bali, Indonesia*

Source: unknown

developed new resistant varieties, but a few years later there was a dramatic and sudden breakdown in resistance. Again, the farmers were back to square one. Throughout this time, the Indonesian government had maintained and even increased the insecticide subsidy programme

at a high economic, human and environmental cost, and with no positive results in terms of pest control.

Finally, in the mid-1980s, after many researchers were able to demonstrate that the rice planthopper was in fact an insecticide-generated problem, and after strong pressure from civil society, the government took a bold step and banned 57 insecticides for rice, eliminated insecticide subsidies and started a comprehensive Integrated Pest Management (IPM) programme in rice. Since then, many more studies have demonstrated that the rice ecosystem is a complex system that supports high levels of biodiversity, including many natural enemies that act as biological controls of rice pests. Studies have also shown complex interactions that include links between organic matter and generalist predators through complex trophic cascades, similar to that described earlier for the coffee agro-ecosystem, and well known in other grain crops. Bacteria and phytoplankton are the base of the aquatic food web in irrigated rice fields. In this case, a rich organic 'soup' originating from crop residues from previous cycles, organic waste brought from villages with irrigation water, and algal growth, increases the abundance of detritivores and plankton feeders, which in turn support the populations of generalist predators, which feed on herbivores. It has also been demonstrated that the rice plant can withstand up to 60 per cent damage without reducing yields, and even higher levels with little yield reductions. Furthermore, it seems that the heterogeneity of the landscape also contributes to pest control. This goes against the idea that synchronous planting over a large area helps control pests because the fallow period (when the fields lie barren and dry for a long period) acts as a bottleneck for the pest population. Comparative studies in Indonesia and Malaysia showed that outbreaks of the rice brown planthopper are more prevalent and severe in synchronously planted areas with continuous rice fields that cover thousands of hectares than in non-synchronously planted areas dominated by smaller rice fields interwoven with natural and home garden vegetation. The reason for this appears to be that in the synchronously planted areas, predators take a much longer time to arrive in the fields than in the non-synchronously planted fields, where predator populations can continue to build up through the years, and even take refuge in the natural and non-rice vegetation that is present throughout the landscape.⁵⁶

In addition to the decline in associated biodiversity, the Green Revolution in rice also resulted in dramatic genetic erosion, that is, a decline in the landraces of rice, many of which were adapted to the local environmental conditions. Such a decline increases the vulnerability of rice-producing countries, and threatens food security and food sovereignty. The first high-yielding rice variety was released in 1966 and a decade later a few HYVs had replaced thousands of traditional rice landraces previously cultivated by farmers. Since these HYVs are bred to respond to irrigation, pesticide and fertilizer applications and mechanization, they spread in those areas with favourable environmental and political conditions (where

farmers could afford the technology or, as in the case of Indonesia, where the government provided subsidies to make the technology accessible to farmers). Today, most rice fields in Asia are occupied by a few high-yielding rice varieties. For example, in the Philippines, home of the IRRI, 50 per cent of the rice area is planted in four HYVs; in Cambodia only one variety is cultivated in 90 per cent of the rice fields; and in Pakistan, only four HYVs are planted in 99 per cent of the rice fields.⁵⁷ Traditional varieties were collected and stored in national and international seed banks to which farmers do not generally have access. In addition, some traditional varieties are still cultivated in marginal areas, where the HYVs do not perform as well or where farmers can't afford some parts of the technological package.

The story of the rice Green Revolution in Asia illustrates the pitfalls of a narrow technological approach to agriculture. In their efforts to increase yields, researchers and politicians ignored the fact that the rice ecosystems, and their associated landscapes, not only put a bowl of rice on the table of millions of people, but provide for the livelihood of millions of rural people for whom rice is life and culture.

Maize production and the landscape mosaic

The tendency to grow food in large-scale monocultures is not universal, and certainly not very old. Maize is an excellent example of a grain that is frequently produced on a small scale. Even today, traditional maize producers are not clamouring for large extensions of monocultural production. Indeed, in areas of Mexico and Guatemala, where indigenous people still follow traditional agricultural practices, it is commonplace to see maize and beans grown together in the same field, frequently with squash interspersed among the maize and bean plants (Figure 5.12). It is common for the beans, growing as a vine, to use the maize stalk as a trellis, and the squash plants to cover the understorey, choking out undesirable plants. In especially low spots in the field, if locally poor drainage is expected, some other crop such as taro or banana is commonly planted instead of the maize/bean mixture. So a typical maize field, or *milpa*, is frequently a combination of species that take advantage of special features of the environment (the low poorly drained spot) or of each other's special ecological characteristics (the maize using some of the nitrogen the beans fix from the air, the beans using the maize stalk as a trellis) – not at all a true monoculture. Indeed, from our experience of talking with such farmers, their attitude is that it would be foolish not to take advantage of these special ecological conditions when planning the farm.

However, for the arguments presented in this book it is not so much the micro-management of an individual maize field that matters, but rather the landscape patterns that emerge from individual farmers managing small parcels of land in ways that are dictated by ecological imperatives (Figure 5.13). The environment in which much traditional maize farming



Figure 5.12 *A milpa in southern Mexico.*

Note: *Milpa* is a corn-based growing system used throughout Mesoamerica that typically includes corn, bean and squash. In this system the various components facilitate each other.

Source: John Vandermeer

is carried out is situated on soils that are characteristically poor at storing nutrients. Thus, a bit of potassium (say) in the soil will rapidly leach out of that soil with the next rain if the crop does not immediately take it up. This is quite different from the rich soils of temperate latitudes where the details of soil structure actually hold that potassium in place over many years, like a nutrient bank. This metaphorical bank simply does not exist in many tropical soils. Consequently, the nutrients (nitrogen, potassium, phosphorus, calcium, etc.) in tropical ecosystems are contained in the vegetation of the system, more than in the soil. So, when a farmer cuts down and burns the natural vegetation to make a farm field, he or she effectively takes almost all the nutrients in the system and places them in the soil all at once. In the end, those nutrient elements that are not taken up by the crops, almost completely leach out of the system when the rains come.

The inefficiency of many tropical soils at maintaining nutrients means that crop production dramatically drops after a few years of production. This drop in production means that the farmer must cut down a new piece of vegetation to begin the process again, leaving the previous cropped



Figure 5.13 *A slash and burn landscape mosaic in Belize*

Note: In the centre there is an area that was recently cut and burned and is being prepared for planting. The rest of the landscape consists of areas that are either in cultivation or at various stages of succession.

Source: Sustainable Harvest International

field in fallow. This cycle of slashing the vegetation, burning it, cropping it and subsequently leaving it fallow is referred to as 'slash and burn' or fallow agriculture, and was certainly the dominant form of producing grains the world over prior to the imposition of the industrial system.⁵⁸ The fallow field would inevitably go through the normal period of ecological succession, with pioneering vegetation establishing in the abandoned field and accompanying any resprouting trees and other woody vegetation that remained alive, followed by the establishment of successional species in the march towards a second-growth forest. In 10 to 20 years, the vegetation grows back to form a secondary forest with high levels of nutrients stored within the vegetation. At that point, the forest is ready to be cut again in a continuous cycle of cultivation and fallow. Exactly how long it takes for a particular piece of land to grow back to the point when it is ready for the next cultivation depends on the properties of the soil, the amount of rain and the type of vegetation that grows during the fallow period. Farmers frequently use indicator species to decide when the fallow is ready to be cultivated again. In some places, farmers shorten the fallow period by planting species of trees that accelerate the successional process or increase the amount of nutrients available in the ecosystem.

Among the important consequences of this traditional system of agriculture is the overall landscape that it creates. An individual farming family or collective must have enough land available to it to be able to set aside

relatively large amounts of land to be in fallow between cropping cycles. Leaving 80 or 90 per cent of the land in some sort of recovery stage creates a patchiness of habitats in the landscape reminiscent of the landscape mosaic we described in Chapter 2. Thus, in this traditional mode of maize production, the expected landscape is a mosaic that may provide for a high-quality matrix through which organisms migrate, thus creating the sort of matrix that promotes successful metapopulation structures in the patches of natural vegetation that remain. Indeed, it has been suggested that this form of agriculture actually creates the conditions for higher biodiversity simply because of the habitat heterogeneity it generates.

Nevertheless, recent trends in agriculture have replaced much of the extant traditional maize production (certainly not all), and we must question how future production in traditional maize-producing regions can be organized so as to provide a high-quality matrix for conservation. Leaving large areas in fallow would probably be a good idea but is unfeasible, although the simple notion of a fallow should always remain part of the agricultural planning process (at least in the tropics). However, as has been pointed out by Wes Jackson and others, examining the way the natural world works is a good way to gain ideas for planning agroecosystems. In many ways, the world's ubiquitous rotational systems actually mimic, to some extent, the fallow period (e.g. soybeans are the fallow period from the point of view of maize, in a maize-soybean rotational system). In this way more modern, but still non-industrialized, tropical farmers tend to use complex rotational systems in which maize is a part, but in which beans, squash, vegetables and some trees, form an equally essential part of the rotational system.

For example, on a traditional farm we recently visited in Chiapas, Mexico, a patchwork of small fields (each approximately a quarter of a hectare) contained maize, beans (sometimes in combination, sometimes separate), broccoli, cabbage, carrots and cassava, and were bordered by several small fruit trees (especially papaya), with the ubiquitous large mango tree in one corner of the farm. Mixed in with all these fields were several that had not been planted at all and were in various stages of succession (Figure 5.14). While this farm did not look like native vegetation to us, its mosaic nature resulting from small-scale planting decisions created a mosaic that undoubtedly seemed more like some sort of native vegetation to many different kinds of plants, fungi, animals and other organisms. This was also an organic farm, and the lack of agrochemicals ensured that small insects migrating into one of the fields would have a good chance of reproducing individuals that could migrate to other fields before expiring themselves. In short, this farm created a landscape that was not natural vegetation, nor the sort of high-quality matrix that a rustic coffee farm represents, but that formed a landscape mosaic that would probably ensure successful migration of many kinds of organisms. It is, in our view, a model that could be emulated, especially in the context of a political system that promotes the idea of food sovereignty.



Figure 5.14 *A diverse organic farm near San Cristobal de las Casas, Chiapas, Mexico*

Note: The farm consists of a patchwork of small fields of various crops, some fruit trees and patches at various stages of succession.

Source: John Vandermeer

Response from the social movements: where biodiversity conservation meets food sovereignty

Rice and maize present excellent examples of the type of win-win situation that could ensue when the proper ecological, socio-economic and cultural conditions are developed. Given the importance of rice for the culture, nutrition, income and overall livelihood of millions of people in Asia, it is not surprising that the small-scale farmers' organizations and grass roots social movements in the region are taking a strong stand under the slogan 'Rice is not a commodity: it is life, culture and dignity!' In May 2006, they released a declaration during the Asia Pacific Peoples Conference of Rice and Food Sovereignty (Box 5.1). In this declaration, the participants urged their governments to adopt policies to promote sustainable rice production and family farm-based production. The revival of traditional rice farming practices that rely on high levels of aquatic and terrestrial biodiversity, as well a high diversity of landraces was one of the points within the resolution.

Box 5.1 *Rice is Life, Culture and Dignity*

Final Declaration of the Asia Pacific People Conference on Rice and Food Sovereignty Jakarta, Indonesia, 14–18 May 2006

We the peasants from Asia and Pacific strongly voice our right to have a better life, to preserve our cultures, and protect the dignity of the people. Rice has been our staple food for centuries, so it is a political issue. Therefore, we demand food sovereignty for the people. Farmers should have the rights to produce food in a sustainable way and be protected from neo-liberal policies. Food sovereignty should prevail over free trade.

Women peasants have protected traditional rural agriculture and sustainable agriculture in their communities for centuries. Therefore, they should be respected and have the same rights as men. Their rights and access to production resources should be protected because women are the main force of production. Women peasants will implement a detailed action plan to protect sustainable agriculture and food sovereignty.

We gathered to formulate the principles of food sovereignty on rice. We urge our governments to adopt policies promoting and supporting sustainable rice production and family-farm-based production rather than agro-industry, export-oriented and high-input rice production. During our discussions, we realized that people's food sovereignty should be implemented at different levels: the access and control over natural resources (land, water and seeds), the choice of the mode of production and consumption, and the kind of trade that we want.

1. *Land, Water and Seeds*

- We demand a genuine agrarian reform that focuses on land distribution to the landless people and provides possibilities for farmers to retain land in their possession.
- Land to the tiller: the land should belong to the small and landless people, and not to landlords and big companies.
- Land and water have to be owned by the local communities with all respect to the community's legal and customary rights to their local and traditional resources.
- It is not enough to have some positive laws. In Asia and Pacific, many countries have agrarian laws, but they are not implemented. Social movements have to be able to pressurize and monitor the implementation of the laws.
- Women should have equal rights in terms of their access to land water and other productive resources.
- We condemn the privatization of water. Water is now being controlled by multinational corporations. Governments have to protect their farmers in order to provide them with free irrigation access for production.
- We should be protected from the pollution of the water sources by industry and chemical farming, especially in rice production systems.

- Seeds are at the heart of agriculture, they are the basis of food sovereignty. We should abolish all patents on seeds, as well as rejecting any means, system or technology that prevents farmers from saving, improving and reproducing seeds. We categorically say no to terminator technology on seeds that curtails this freedom.
- We encourage the right to exchange and reproduce seeds by the people and for the people. Seeds can not to be distributed by the multinational corporations and the governments, as they will make the farmer only the end-user in the chain of seed production.
- We must abolish genetically modified organisms (GMOs) and ban their production and trade in rice seed.

2. Rice Production Systems

- We condemn the green revolution because it destroys biodiversity, fosters dependency on chemicals, leads to environmental degradation and displaces many small farmers from their livelihoods and land.
- We promote sustainable rice production such as organic and natural farming: they use less input and produce better quality outputs.
- We encourage the revival of traditional experience on sustainable rice production systems; for instance, the natural farming in India (Karnataka).
- We recognize the importance of food sovereignty in terms of nature and ecology in order to create poverty eradication, protect the ecosystem, land preservation and biodiversity, improve health conditions, and improve water quality and food at an affordable cost.
- We must establish rice quality criteria in favour of people's preferences and needs.
- We must strongly push our governments to give support to organizations who promote sustainable agriculture, and to set up formal policies to promote sustainable rice production systems.

3. Post-Harvest Activities and Processing

- Develop local rice economies based on local production and processing by farmers.
- Processing activities and local trade should be managed by small family units, with cheap and people adapted technologies.
- The governments should provide a services programme supporting production and land productivity. They should also facilitate post-harvest activities.

4. Trade

- We should ensure adequate remunerative prices, and the government should guarantee it through subsidy to cover the costs of production and also to get adequate profits that are related to the cost of living of the farmer.
- We should abolish all direct and indirect export subsidies, ask the government to give a subsidy for promoting sustainable rice production and make sure that the subsidies do not go to the multinational corporations and large producers.

- The governments must support farmers who produce rice for domestic needs.
- Domestic production should be regulated to prevent surpluses.
- We must ban rice imports when countries can produce enough for their own consumption. Most of the time, rice imports are only surpluses dumped on our countries and they kill farmers.
- We should promote family-based rice farming to ensure the domestic rice need and self-sufficiency. We condemn the liberalization of the rice trade pushed by the WTO and the Free Trade Agreements. And we demand that WTO get out of food and agriculture.

Rice is not only a commodity: it is life, culture and dignity!

Organizations (peasant organizations and civil organizations and NGOs) endorsing this declaration are:

Assembly of the Poor (AOP) of Thailand
 PARAGOS of the Philippines
 UNORKA of the Philippines
 Viet Nam Farmers Union (VNFU) of Viet Nam
 Hasatil of Timor Leste
 ANPA of Nepal
 KRRS of India
 BKU of India
 MONLAR of Sri Lanka
 National Family Farmer Coalition (NFFC) of United States
 Korean Peasant League (KPL) of South Korea
 Korean Women Peasant Association (KWPA) of South Korea
 Federation of Indonesian Peasant Union (FSPI) of Indonesia
 Petani Mandiri of Indonesia

Similarly, maize is an important cultural as well as nutritional element in much of Latin America. Indeed, according to the Mayan creation myth, the god Popol Vuh made people from maize. In Mexico, a coalition of peasants, farm workers, indigenous people, fishers, consumers and environmental and human rights organizations have launched the National Campaign in Defence of Food Sovereignty and the Revitalization of Rural Mexico, under the slogan 'Sin maíz no hay país' (without maize we have no country). According to the national newspaper *La Jornada*, in January 2008 more than 200,000 people marched in Mexico City to demand that NAFTA's agricultural chapter be renegotiated. Among the main points of the campaign are the protection and improvement of the genetic heritage of Mexican maize, support for the production of organic and native maize varieties, and forest conservation through community-led sustainable management of natural resources (Box 5.2).

Box 5.2 *Ten Urgent Steps for Mexico*

The National Campaign in Defense of Food Sovereignty and the Revitalization of Rural Mexico calls on all Mexicans to join together in support of protecting Mexican maize, defending Mexico's food sovereignty and revitalizing the Mexican countryside. They outline ten urgent steps that need to be taken:

- 1 Remove corn and beans from NAFTA: install a permanent mechanism for the management of imports and exports of corn and beans (and their derivatives and by-products) by the Mexican Congress.
- 2 Ban the planting of transgenic corn in Mexico: protect and improve the genetic heritage of Mexican corn, and encourage the production of organic and native corn varieties.
- 3 Approve the Constitutional Right to Food by the Mexican Chamber of Deputies and the Law on Planning for Sovereignty and Food Security and Nutrition by the Mexican Senate.
- 4 Fight the food sector monopolies: prevent hoarding and speculation, and misleading advertising of junk food.
- 5 Promote Mexican corn and cultural expressions.
- 6 Control prices of the basic food basket: ensure adequate food supply and create a strategic reserve of food; and promote the consumption of fair trade and small producer-produced food.
- 7 Recognize the rights of peasants and the rights of indigenous peoples to their territories and its natural resources.
- 8 Support higher prices for coffee growers and their access to international markets.
- 9 Promote the conservation of the forests through community-led sustainable management of natural resources.
- 10 Ensure the principle of gender equality in rural policies, as well as the full recognition of the human rights of all citizens, including labour, farm workers and migrant workers.

And they call on Mexicans everywhere to:

- Plant corn in homes, sidewalks, *camellones* and public parks throughout the country.
- Sign and support the ten steps to defend corn and the Mexican countryside.
- Participate in the National Day of Mobilization for the Defense of Food Sovereignty and the Revitalization of Rural Mexico and the 2008 rural budget.
- Educate, organize and act to denounce monopoly agribusiness abuses, and promote the production and consumption of fair, healthy, organic, non-GM foods produced by small farmers.
- Support the efforts of peasant and indigenous organizations' demands for justice, health and sovereignty for Mexico.

AGRICULTURAL POTENTIAL IN THE MATRIX

The foregoing description of both the history and functioning of various agro-ecosystems we hope leaves the reader with the impression that 1) the industrial system has had a peculiar political and social evolutionary pathway, depending on economic and political forces as much as on ecological contingencies, and that 2) the alternative movement, as well as extant and extensive systems such as coffee and cacao, along with diversified landscape mosaics, show that the image of the pesticide-drenched soybean field is not the only kind of agriculture possible. This point becomes central to our general argument that transforming the agro-ecosystem into a high-quality matrix is possible given the realities of agriculture, as much as it is essential for conservation. We return to this basic point in our summary in the next chapter.

NOTES

- 1 Perfecto et al (1996); Moguel and Toledo (1999); Perfecto and Armbrrecht (2003).
- 2 Perfecto et al (1997).
- 3 Erwin (1982).
- 4 This literature is summarized in Perfecto and Armbrrecht (2003) and Perfecto et al (2007).
- 5 Menon (2006).
- 6 Rice (1999).
- 7 Moguel and Toledo (1999).
- 8 Perfecto and Armbrrecht (2003).
- 9 Armbrrecht et al (2004).
- 10 Moguel and Toledo (1999).
- 11 Also known as the black penelopina (*Penelopina nigra*).
- 12 BirdLife International (2007).
- 13 Perfecto and Vandermeer (2002).
- 14 Vandermeer et al (2002b).
- 15 Armbrrecht and Gallego (2007).
- 16 Le-Pelley (1973).
- 17 Perfecto et al (2004). Although the initial intent was to exclude birds, the enclosures also excluded bats because they were left overnight. Therefore, the effect observed could have been due to bats or both bats and birds. Indeed, research conducted a few years later demonstrated that bats also have an effect on arthropods in coffee (Williams-Guillen et al, 2008).
- 18 Perfecto et al (2004).
- 19 Williams-Guillen et al (2008).
- 20 Its full scientific name is *Azteca instabilis*, but we will continue referring to it as *Azteca* only – it has no common name. For more details of this system see Vandermeer et al (2002a); Perfecto and Vandermeer (2006; 2008b); Vandermeer and Perfecto (2006); Liere and Perfecto (2008); Vandermeer et al (2008).
- 21 Actually, this example is even more complicated than we indicate here. The effect of the fly is to change the behaviour of the ant so that its foraging activity

- is dramatically reduced. The colony, thus weakened because of the reduced foraging efficiency, is subject to any of a variety of mortality factors.
- 22 Perfecto and Vandermeer (2008b).
 - 23 Reported in Bio-Medicine, <http://news.bio-medicine.org/biology-news-2/USAID-Conservation-International-26-Starbucks-launch-Conservation-Coffee-Alliance-in-Central-America-68-1>, accessed 26 February 2009.
 - 24 Conservation International (2007).
 - 25 Johns (1999).
 - 26 Wright (1976).
 - 27 Mittermeier et al (1998).
 - 28 Alves (1990).
 - 29 Rice and Greenberg (2000).
 - 30 Because one of the most common ways of demonstrating economic use was to cut the forest, this provision of law has been devastating to Brazilian forests.
 - 31 Wright and Wolford (2003).
 - 32 The term 'primary forest' is probably a misnomer in almost all cases in Bahia, where there may be no forest that has not been cut over at some point.
 - 33 Aguilar Støen (2009).
 - 34 FAO (1996).
 - 35 Paris et al (2000).
 - 36 FAO (2004).
 - 37 FAO (2004); Halwart et al (2006).
 - 38 Meijem (1940); Weerakoon (1957); Fernando (1995, 1996); Odum (1997); Bambaradeniya (2000a, b); Bambaradeniya and Amarasinghe (2004).
 - 39 Bambarayedina (2000a).
 - 40 Much of the information presented in this section comes from Bambaradeniya and Amarasinghe (2004).
 - 41 Weerakoon and Samarasinghe (1958); Fernando et al (1979); Fernando (1980a, 1980b, 1993); Yano et al (1983); Lacey and Lacey (1990); Rozilah and Ali (1998); Bambaradeniya and Amarasinghe (2004).
 - 42 Ooi and Shepard (1994); Way and Heong (1994); Settle et al (1996).
 - 43 Smith (2001).
 - 44 Trigo and Cap (2003).
 - 45 Way and Heong (1994); Amir Shah Ruddin and De Datta (1998); Halwart (2006).
 - 46 Halwart et al (2006).
 - 47 Relyea (2005a, b).
 - 48 Moody (1989); Bambarayedina (2000a).
 - 49 FAO (2004); Halwart and Bartley (2005); Halwart et al (2006).
 - 50 Hansen et al, 1998; Elvevoll and James (2000); Roos et al (2002); Halwart (2006).
 - 51 Halwart (1999).
 - 52 Balzer et al (2005); Luo (2005); Halwart et al (2006).
 - 53 The following section on the history of the rice Green Revolution in Indonesia is based on the account by Settle et al (1996).
 - 54 This self-sufficiency was of short duration since they have been importing rice since the mid-1990s. However, in December 2008, the Vice President of Indonesia, Jusuf Kalla, announced that they would not be importing rice in 2009 because the country's rice production target had been achieved.
 - 55 The IRRI is an international agricultural research and training organization established in 1960 with support from the Ford and the Rockefeller Foundations,

in collaboration with the government of the Philippines to promote the Green Revolution in rice in developing countries, especially in Asia. It is part of the Consultative Group on International Agricultural Research.

56 Sawada et al (1991); Seattle et al (1996).

57 IRRI (2004).

58 Kleinman et al (1995).

The New Paradigm

RECAPPING THE ECOLOGICAL ARGUMENT

The theory of biodiversity

The science of ecology has long sought to understand the nature of biodiversity, while the conservation movement has traditionally taken as its core goal the preservation of biodiversity. It would be surprising indeed if the science itself had not by now come to some agreement on the nature of its subject matter. We have already described in great detail in Chapter 2 the modern ideas of how biodiversity is maintained. We also alluded to the fact that this is still a contentious and evolving corner of the scientific world. However, we also noted that if the cobwebs of that contentiousness are wiped away, a core of ideas emerges, a kind of conventional wisdom among ecologists as to how biodiversity 'works'. It begins with the idea of a metapopulation and focuses on the balance between the perfectly natural tendency for populations to go extinct locally and the tendency for individuals in those populations to migrate to new locations.

The fundamental idea is metaphorically related to the way infectious disease works. An individual person becomes sick, transmits the sickness to another person and then gets well. That sort of says it all. Becoming sick is the invasion of a disease organism into the habitat, which is to say, into the body of the host. But the main purpose of the disease organism is to infect someone else, which is to say, migrate to a new habitat. And that migration has to happen before the person's immune system causes a local extinction, which is to say, cures the body of the disease. So, in this metaphor, the human body is the habitat, the organism causing the disease is the population of concern and the transmission rate from person to person is the migration rate from habitat to habitat. The recovery rate, which is a good thing for the person, is a bad thing for the disease organism because it is a local extinction of that organism. The disease organism can persist over the long run only if its transmission rate is sufficiently large relative to the recovery rate – if its migration rate is sufficiently large relative to its local extinction rate.

It is now fairly well accepted that many populations in Nature are subjected to patterns that are similar, formally known as metapopulations. Whether the non-random distribution of trees in a forest or the variable occupation of temporary ponds by amphibians, subpopulations are to some extent isolated from one another, and these subpopulations are

subjected to many forces that cause a complete elimination of the population from its local environment – a local extinction. However, provided other subpopulations continue to provide propagules, the site originally occupied by a subpopulation that has gone extinct will eventually receive one of these propagules – a regional migrant will arrive. As long as the migration rate balances the extinction rate, the population will survive over the long run as a metapopulation.

To be all-inclusive, this framework must be viewed from three inter-related points of view. First, in a continuous habitat the fundamental process may operate only in an indirect fashion, although even here there is growing evidence that it is a basic rule of Nature. Second, a habitat that is variable such that some sub-habitats are more conducive than others for the survival of a particular species, is probably the most important structural framework in the natural world before the rise to dominance of *Homo sapiens*. Third, in the human-dominated landscapes we live in today, native habitats remain as isolated fragments in a matrix of managed ecosystems, mainly agro-ecosystems. The basic metapopulation framework operates in varying degrees in all three cases, as we summarize presently.

In continuous habitats it is not easy to establish beyond doubt the existence of metapopulation structures. There is some evidence that the internal dynamics of populations will generate non-random distributions of individuals in space (trees in a tropical forest, for example) and at least one detailed analysis of two different forest sites (in Panama and Ecuador) suggests that most of the tree species indeed have clustered distributions at some spatial scale.¹ Given such clustered distributions, it is likely that mortality effects (individual trees dying) will be related to those clusters since diseases and other natural enemies are likely to encounter these individuals more frequently when they are clustered. Some vertebrate species (e.g. monkeys and wolves) occur in clusters because they are social. Any disease epidemic may act to kill all the individuals in the cluster (family group), being, in effect, a local extinction event. Many other possibilities could be cited in which, even in continuous uniform habitats, populations are likely to have metapopulation dynamics.

In heterogeneous habitats, the existence of metapopulation structures is more evident. Islands and habitat islands are the rule rather than the exception for most species. For example, most amphibians play out an important phase in their life cycle as larval forms (tadpoles) in habitat islands (ponds and lakes). Sequential sampling of temporary ponds in Michigan, for example, revealed about 30 extinction events in an area that contained only 17 species of amphibians (ponds containing a particular species at one time did not contain that species 20 years later).² Furthermore, some heterogeneous habitats result from biological interactions that produce evident spatial patterns in formerly uniform environments, as might happen with beaver ponds resulting from beavers building dams. The consequent beaver dams present a heterogeneous habitat for many other species not involved in those interactions, the fish that live in the

beaver ponds, for example. These later species then are likely to exist in a metapopulational situation.³

In fragmented habitats (which are the most important type since they are probably the most common landscapes in the contemporary world), the same situation exists as in heterogeneous habitats. The clusters of individuals that may have existed in the continuous habitats before fragmentation are certainly going to be subject to metapopulation dynamics after fragmentation.

What all these situations have in common is that the death of individuals in a cluster is common, when viewed over the long term (e.g. a family of monkeys subject to an epidemic or a group of trees completely defoliated by a herbivorous insect population attracted to the local abundance of the tree). The death of all the individuals in a cluster represents a local extinction (the disappearance of that cluster), a fact that is effectively inevitable if taken over a long enough period of time. Local extinctions are thus inevitable, whether caused by humans or not. What stops local extinctions from becoming global (the extinction of the species itself) is the balancing migration that occurs among clusters of individuals or among patches of habitat. Thus, for example, in the case of the 30 extinctions of 17 species of amphibians over a 20-year period, those local extinctions were balanced by almost exactly the same number of migrations. And the basic metapopulation equilibrium of $p = 1 - e/m$ (proportion of habitats occupied is one minus the ratio of extinction to migration) assures us that each of the 17 species of amphibians remains, through the dynamic pattern of extinction and remigration.

High extinction rates in isolated fragments

If small nature reserves are viewed as fragments in a larger matrix, the concept of the metapopulation immediately comes to mind – a core idea in this book. Each fragment is a subpopulation that need not provide all the necessities to maintain a population in perpetuity, but exists in the context of other fragments that provide propagules for species that have gone locally extinct because a particular fragment is too small to maintain a population over the long term. An important result already cited in Chapter 2 is from long-term experiments on forest fragmentation in Amazonia.⁴ While smaller fragments of forest have higher avian extinction rates than larger ones, the actual extinction rates of even the largest patches are surprisingly high. Indeed, some are so high as to suggest that the only acceptable size for a biological preserve is one that is far beyond reasonable expectation under current political circumstances. Similar studies were discussed in Chapter 2. The remarkably high extinction rates for smaller patches contain important lessons for conservation in fragmented landscapes, one of the main messages of this book.

From recent theoretical studies we might expect that for some organisms the spatial extent necessary for their conservation may be unusually large,

far beyond what any current or imagined future political arrangement might tolerate, or even what may be available in natural/unmanaged habitat. As an example, an influential recent analysis postulates that recruitment limitation (or failure to disperse to suitable habitat patches) is one key factor in maintaining tropical tree diversity.⁵ Long distance dispersal events, under this formulation, are important in maintaining species diversity over the long term. Therefore, fragmenting the forest and consequently limiting the rare dispersal event in the original spatially extended forest is likely to cause local extinctions and a concomitant reduction in regional biodiversity. Unfortunately, such expected extinctions are likely to occur far into the future, making the political case for conservation here and now very difficult. However, our point here is that fencing a patch of forest in no way guarantees the protection of biodiversity in perpetuity, since rare migrations (seed dispersal events) from far away are essential.

From these empirical and theoretical studies we are forced to face the unpleasant conclusion that for some species, protecting a sufficiently large area to avoid major extinctions may not be possible. This conclusion is not meant to imply some sort of surrender, but rather to emphasize a necessary change in focus for conservation planning. The matrix matters, to repeat again the basic theme of this book.

RECAPPING THE AGRICULTURAL ARGUMENT

The current world consists mainly of fragments of native or 'natural' habitats. The largest biodiversity preserve in the world is Tanzania's Selous National Park (21,000 km²) and even it appears as a tiny fragment on the globe as a whole. National Parks and biological preserves claim outstanding success in biodiversity conservation the world over, yet there remains an extremely large amount of biodiversity outside of designated natural reserves, scattered in fragmented landscapes from Siberia to the Congo. It is thus critical to view conservation at a landscape level, in which fragments of native habitat almost always exist, but the majority of which are embedded within some sort of agro-ecological matrix. Our argument is that there is no particular reason to view the fragments or their surrounding matrix as any sort of Heaven and Hell, and quite certainly not as systems that can or should be treated independently by conservationists or developers. In this context, our approach rejects a focus exclusively on habitat fragments, and proposes that the general dilemma can be better addressed with an increased focus on the matrix and, following current ecological understanding, the interactions it has with remaining fragments of 'natural' habitats.

Increasing agricultural production for conservation

Approximately 90 per cent of the terrestrial surface of the Earth is outside of reserves and is used or managed by human beings in one way or another.⁶ In the tropics approximately 70 per cent of the land is pastures, agriculture or a mixture of managed landscapes.⁷ In the popular and romantic conceptualization of Nature as a Garden of Eden, many conservationists view agriculture as the defining feature of biodiversity loss. The world is divided into those areas untouched or minimally touched by *Homo sapiens* as contrasted to those areas despoiled by human activity.⁸

Many recent ecological studies have challenged this perception, the two most obvious examples being shade-grown coffee and cacao, as elaborated in Chapter 5. As both of those examples (and many others) illustrate, when dealing with managed ecosystems it is first necessary to distinguish between two concepts of biodiversity. First is the collection of plants and animals that the manager has decided are part of the managed system – rice in the paddies of Asia, maize and beans in the traditional fields of Native American Mayans, carp in the fish ponds of China, etc. This is the so-called ‘planned’ biodiversity, to be contrasted with the associated biodiversity, the organisms that live or spend some time in the managed systems but are not intentionally included there by the managers – the fish, aquatic insects and frogs in the Asian rice paddies, the birds and insects that eat the Mayan’s *milpa*, and the crayfish that burrow their way into the sides of the Chinese fish ponds. The pattern of associated biodiversity gain or loss as a function of management intensity is one of the major patterns of biodiversity in the world, as we discussed in Chapter 2. Frequently the managers themselves are determinedly concerned about the planned biodiversity, especially when dealing below the species level (with genetic varieties of crops). However, it is almost certainly the case that the associated biodiversity is the most abundant component of biodiversity in almost all managed ecosystems, and as such, it has received a great deal of attention in recent years. Furthermore, the associated biodiversity may also have important functions in the agro-ecosystem.⁹

The process of intensification of agriculture provides a conceptual framework for analysing the role of agriculture in biodiversity conservation, especially when concerned with associated biodiversity. Although the term ‘agricultural intensification’ has a very specific and complex definition in economic history and anthropology, in biodiversity literature the term ‘management intensification’ or ‘agricultural intensification’ is taken to be the transition from ecosystems with high planned biodiversity to low planned biodiversity and an increase in the use of agrochemicals and machinery.¹⁰ The ecology of agro-ecosystems is such that the final stages of intensification usually include the application of agrochemicals to substitute the functions or ecosystem services of some of the biodiversity that is eliminated.

Conservation biologists often fail to fully acknowledge a component of agricultural intensification that can have devastating consequences: the application of pesticides. Extinction of the world's small organisms should cause as much concern as the extinction of charismatic megafauna.¹¹ Insects, mites, nematodes, microbes and representatives from at least 30 different kingdoms of organisms¹² abound in the soils, leaf litter and other niches in every environment in the world and are highly susceptible to pesticides. An old cotton field in Nicaragua contains almost no ants, as far as our personal informal faunal surveys could determine. Ants in these fields (and most other insects, except those that have evolved resistance) have gradually disappeared due to the massive spraying of pesticides in a failed 30-year experiment with industrial agriculture that not only did not bring riches to the Nicaraguan people, but also contaminated the land for many years after cotton was abandoned.¹³

Recent studies of amphibians have helped to focus this issue. In a series of studies from the University of California, Atrazine has been found to have complex effects on various species of amphibians.¹⁴ While the popular press has picked up on those studies because of their implications for human health (Atrazine is a chemical that has a similar action to oestrogen), the effects on the amphibians themselves is worrisome regarding their ultimate survivability. In similar studies examining the effect of the herbicide Roundup on the larvae of three species of amphibians, mortality rates of over 90 per cent were reported.¹⁵ These results are surprising given that glyphosate, the active ingredient in Roundup, had been reported to have minimal toxicity on vertebrates.¹⁶ However, the commercial formulation of this herbicide contains a surfactant to assure that the active ingredient adheres to the leaves of plants, and it appears to be the combination of these ingredients that causes the high mortality of amphibians. Regardless of the details about the mortality mechanisms, the main conclusions of these studies are clear and robust: two of the world's most extensively used herbicides kill amphibians. Given the dynamic turnover pattern of many species of frogs and salamanders, and the fragmented nature of most terrestrial ecosystems, it is essential that these species be able to move through the agricultural landscape to find new breeding ponds.¹⁷ The use of Atrazine or Roundup in the agroecosystem might thus condemn many amphibian species to extinction. In this context, the expansion of Roundup Ready transgenic soybean production in Brazil, Argentina, Paraguay and Bolivia¹⁸ is of concern.

Intensification, food production and biodiversity conservation

The increasing demand for food has led some agriculture and development advocates to argue that the best option to meet the challenges of increasing food production and conserving wildlife is to increase yields by intensifying agriculture and spare land for conservation.¹⁹ This position is

based on two assumptions. First, that agricultural intensification leads to land sparing, and second, that there is a productivity trade-off: in other words, that the biodiversity value of farmland (including organic and agro-ecological methods) declines with increasing yield.²⁰ These two assumptions need to be examined more carefully.

Intensification does not take place in a socio-political vacuum. Frequently, regions that experience agricultural intensification also experience increased economic activity, higher demand for products and services, immigration, road construction, and consequently, in many cases, higher deforestation rates.²¹ Furthermore, intensification frequently results in the displacement of small-scale farmers and agricultural workers who then move into nearby marginal land or the agricultural frontier, frequently causing more deforestation elsewhere.²²

However, the assumption that agricultural intensification leads to land sparing is seductive in its simplicity. Given an arbitrary area, we begin by assuming that there is a target, T , for production of some commodity in that area. Then we can easily construct a simple production function that associates proportion of land in production with total production on that land, in which case we always see an increasing pattern, usually with diminishing returns (see any economics textbook, for example, Simon and Blume²³). That function will always increase with intensification (by definition). This means that production will always increase with intensification, according to this model framework. To meet the target production of T , we see that the amount of land necessary to be put into agriculture is always less with increased intensification. This simple approach can be embellished with all sorts of other interesting factors such as discount rates, land rents, input market uncertainties and many others. We have added, for example, to this basic idea the value of biodiversity itself.²⁴

The problem is not with the actual model and certainly not with the more sophisticated elaborations of the basic idea. The problem is with the basic framing of the problem in the first place. Rarely is it actually of interest to know what a 'target' for production is. Vague notions, such as the world's calorie requirements, have little to do with decisions that are made at the farm, or even regional levels. Indeed, in most parts of the world, if there is a 'target' it is to maximize return on investment, which is only indirectly related to a production target. Farmers frequently fail to engage in particular practices not because they are less productive, but rather because they require a large cost for labour or capital outlays. In the end, the framing of an area with the duo of 'land sparing' (or set-asides, reserves or wildlife refuges) and 'agriculture with improved technology' is wrong. Of course, working from within that framing it is difficult to avoid the conclusion that less land will be required for agriculture if it is intensified, thus leaving more land for set-aside. But that is sophistry, even if unintended.

Angelsen and Kaimowitz take a far more sophisticated approach, noting first that there is a fundamental contradiction that is sometimes

ignored.²⁵ First, 'the belief that technological progress in agriculture reduces pressure on forests by allowing farmers to produce the same amount of food in a smaller area has become almost an article of faith in development and environmental circles'. Second, 'basic economic theory suggests that technological progress makes agriculture more profitable and gives farmers an incentive to expand production on to additional land'. Angelsen and Kaimowitz report on detailed studies that sometimes support one, sometimes the other point of view. We conclude that the 'article of faith' that 'intensification of agriculture reduces pressure on forests' is not supported by data.

In a more extensive work, the same authors edited a series of chapters that include 17 case studies from Latin America, Africa and Asia.²⁶ Their conclusions from all these studies is that the issue of intensification of agriculture and its relationship to deforestation is complex and, effectively, that agricultural policy could be modified in such a way as to promote forest-preservation policies rather than policies that, however unintentionally, actually promote more deforestation with 'improved' agricultural technologies. From this analysis, it is difficult to avoid the general conclusion that, for the most part, conventional agricultural intensification causes more deforestation. Granted, the situation is complicated by many factors, and it is certainly sometimes the case that improved agricultural technology has decreased deforestation rates. But examining closely the 17 case studies presented, in 12 of them there was a clear indication that technological change had an effect on deforestation. Of those 12, 9 showed *increasing* deforestation as a result of intensification or new agricultural technology (3 of the 9 suggested it could go either way, depending on circumstances), and only 3 suggested a necessary decrease in deforestation with intensification. All cases were treated with the complex analysis they deserve, and in our view, negate the simplistic assumption that agricultural intensification leads to land sparing.

The second assumption of the 'intensification-land sparing' argument is that there is a productivity-biodiversity trade-off. In other words, that those agricultural technologies that increase yields decrease biodiversity. The assumption is effectively true in the case of industrial agricultural production systems, especially those following Green Revolution technologies. However, the situation is more complicated when examining other, more complex agro-ecosystems. For example, reviews comparing organic and conventional agriculture present evidence that, on average, low-input organic farming has the potential to produce as much as industrial farming, but without the negative environmental impacts.²⁷ Other studies report on specific cases in which organic is less productive²⁸ and polemics can be constructed on both sides of the issue. However, most recently a team from the University of Michigan that includes one of the authors (Perfecto) reviewed close to 300 studies that compared 'organic-like' productive activities with conventional ones, and found that, while individual studies could be cherry-picked to support either side of the

issue, on average there is no evidence that conventional methods outperform organic ones in terms of productivity.²⁹ Furthermore, these organic agro-ecological systems (including organic agriculture, 'natural systems' agriculture, permaculture, etc.) have been shown to be generally more biodiversity-friendly than conventional farming systems.³⁰ Taken in combination, these studies strongly suggest that a biodiversity-productivity trade-off is not necessarily real. In other words, it is possible for some highly productive farming systems to maintain and promote biodiversity. As we discuss in detail below, it is not only the conversion from a native habitat to agriculture that matters for biodiversity conservation, but also the conversion of agriculture from a biodiversity-friendly type to a biodiversity-unfriendly type that accounts for most biodiversity loss within agricultural landscapes.

Yet, as we have argued throughout this book, there is another important way in which agriculture and biodiversity are related, one that belies the simple formula of the 'intensification-land sparing' argument. Most biodiversity should not be thought of as 'point source' or local. Rather, the collection of those points, the general landscape, must be taken into account. As we have already argued, the evidence regarding local extinctions even within large fragments of natural habitats, and the importance of the agricultural matrix in facilitating or preventing inter-patch migrations, suggest that agricultural landscapes dominated by diverse, ecologically based systems, are frequently our best bet for biodiversity conservation. These farming systems provide a high-quality matrix through which migrations may occur, thus counteracting the extinction rates of populations that invariably exist in a metapopulational context.³¹ This suggests that a research or development priority should be to develop highly productive and diversity-friendly agricultural systems, in other words, the agro-ecological intensification of farming systems.³² Such systems, from the point of view of biodiversity and, more generally, environmental services, stand in stark contrast to the modern industrial agricultural system.

The matrix as repository for biodiversity

The agricultural matrix may contain a substantial amount of biodiversity, as has been shown for traditional 'shade coffee' systems, *cabruca* cacao, and so-called jungle rubber,³³ or many other examples now adequately documented in the literature.³⁴ While the exact nature of the species encountered in the matrix may not be the same as those encountered in the native habitat, and the matrix may contain many 'fugitive' or 'opportunistic' species, thus far all studies seem to corroborate the fact that certain matrices are 'high-quality' with respect to the biodiversity contained therein.

Nevertheless, the smoke of the underlying prejudices of many conservationists reflects something of an underlying fire. Casual examination

of the 'matrix' in areas where industrial agriculture is the norm leaves little appreciation for its contained biodiversity, from wheat fields in the Ukraine, to tulip plantations in the Netherlands, to maize fields in Iowa, to soybean plantations in Brazil. Yet it is well known that the 'forest edge' habitat is an excellent place to view birds and other biodiversity, and rustic coffee plantations in Mexico contain the same biodiversity in the tree canopy as a natural forest.³⁵ Sampling insects on traditional tropical farms can produce biodiversity records that are close to those of nearby forests, while similar sampling in pesticide-drenched, nitrate-poisoned, mechanically tilled sugar plantations yields little more than fire ants.³⁶ There can be no doubt that some types of agro-ecosystems contain great amounts of biodiversity while others contain virtually none at all.

The framework for dealing with this issue is the intensification gradient, from the less 'intense' and more traditional systems (such as rustic coffee, jungle rubber or diversified rice paddies) to the highly 'intense' modern, chemically based agro-ecosystems, presenting the world with one of the main trends of biodiversity change (as discussed in Chapter 2). Some authors have objected to the use of the word intensification in this context, since more traditional systems are frequently 'intensely' managed (in terms of the density of agricultural activity in time or space), even though external industrial inputs are minimal. However, as a rough illustration of a qualitative idea, we feel it is appropriate to consider the 'intensification gradient' as one that extends from more traditional diverse systems that use few or no external inputs, to those that are heavily dependent on agro-chemicals, tillage and monocultures. With this general qualitative idea we ask, 'What are the biodiversity consequences of changing a system along this gradient?'

The literature on this subject is now growing, but, unfortunately, most biodiversity studies in the past have focused on 'natural' habitats. Such biases towards the study of biodiversity in so-called 'pristine' sites precludes any true generalizations. Indeed, from the few studies that have been done, we can say that biodiversity generally is reduced with agricultural intensification, but the exact form of that reduction strongly depends on the taxonomic group in question.³⁷ For example, as we discussed in Chapter 5, the reduction in ground-foraging ant diversity is most dramatic during later stages of the intensification process in coffee, but the reduction in butterfly diversity is dramatic earlier in the intensification gradient (perhaps because even very diverse coffee plantations remove much of the understorey where the food plants of many specialized butterflies exist).³⁸

There is also a growing body of literature examining cases where planned (intentional) biodiversity is compared to associated (non-intentional or wild) biodiversity in both conventional and alternative agricultural systems. It seems to be a general rule that higher-planned biodiversity has a positive effect on associated biodiversity within the agro-ecological matrix, as well as within local natural forest fragments embedded within the matrix.³⁹

Fortunately, the last decade has seen an increased interest in the study of biodiversity in managed ecosystems, including urban settings. If this trend continues, we will soon be able to sort out many of the scientific questions regarding biodiversity in agro-ecosystems and will be in a better position to develop landscape-level conservation programmes and policies.

Fragment-to-fragment migration

In addition to functioning as direct repositories of biodiversity, we suspect that many fragmented habitats now contain species that function as meta-populations, as stated earlier. If this is so, the equilibrium proportional occupancy of the fragments for any species is expected to be $(1 - e/m)$, where e is the extinction rate and m is the migration rate. If migration rate approaches extinction rate, landscape-level extinction occurs. What, in this situation, determines migration? The probability that an organism will travel from one patch to another depends on the nature of the area over which it must travel. And that area, in this context, is the matrix. A high-quality matrix can be thought of as one that permits an easy migration from patch to patch. Thus, even though a species may not be able to persist in the matrix, it will frequently be the case that it must migrate through that matrix to maintain the functioning of the metapopulation dynamics.

This function of the matrix as the medium through which migration or dispersal of organisms must occur among fragments of natural habitat is reminiscent of the debate over corridors.⁴⁰ To some extent that debate seems to have died down and most conservation biologists do not feel that corridors, at least in their original formulation, function well in biodiversity conservation. On the other hand, a high-quality matrix may very well function in the way that corridors were expected to function, leading to higher richness in fragments and less effective patch isolation.⁴¹

Agriculture as a temporary activity

Agriculture is not forever. Much of the Neotropics is currently comprised of a patchwork landscape of different kinds of agriculture, forming a matrix with both active agriculture and areas at different stages of abandonment. A given piece of land, especially in the lowland tropics, is rarely able to produce in perpetuity, which is the principal reason that so many cultures developed some form of shifting (or rotational) agriculture. Furthermore, the dynamics of urban-rural migration are captive to the vicissitudes of socio-economic forces. For example, there is currently a massive exodus from the rural areas in Mexico as a consequence of the imposition of the neo-liberal model and the flooding of local markets with agricultural goods from the US. Similarly, Brazil, in the last 40 years, has gone from a population that was two-thirds rural to one that is three-quarters urban; conversely, Cuba is currently re-ruralizing due to its agricultural

policies).⁴² Thus, agro-ecosystems are tremendously dynamic and the subject of post-agricultural succession becomes critical for understanding landscape mosaics. The matrix can be expected to be a mosaic of different forms of agricultural production as well as, and perhaps more importantly, different stages of post-agricultural ecological succession.

Understanding this mix of matrix quality requires an understanding of post-agricultural succession, not only the particulars of what happens to a pasture (say) when it is abandoned, but of the impact the type of agriculture practised has on the details of the successional patterns.⁴³ Indeed, it has been shown that the post-abandonment successional pattern is dramatically different for slash-and-burn or traditional agroforestry as compared to pasture or modern intensive agriculture.⁴⁴ Studies of how various components of biodiversity behave, both in terms of the agro-ecosystem itself as well as in the post-agricultural successional process, will be crucial to understanding the details of matrix quality. Unfortunately, such studies are thus far very rare.

RECAPPING THE SOCIAL MOVEMENT ARGUMENT

Perhaps it is nothing new. Across the Global South, the legacy of European and US imperialism and neo-colonialism has always encountered resistance and challenges through political protest, whether the revolutionary changes inspired by Mao or the evolutionary changes initiated by Gandhi. That resistance continues against the most recent manifestation of these historic political and economic structures: the neo-liberal economic policies. In rural sectors, where much of the protest originates, farmers have always sought to enhance their position through political organizing, sometimes dispersed and informal, at other times concentrated and highly regimented and focused. This tendency of rural social movements to be in constant agitation for political progress is probably a worldwide phenomenon, with deep historical roots. However, the particular conditions faced by these movements have been dynamic and evolving, and characterizing them in any general way is fraught with the pitfalls of oversimplification. Nevertheless, there does seem to be a general structural arrangement that has persisted since the later phases of European-US imperialism and still drives, to some extent, the political ecology of much of the contemporary world, as described in Chapter 4.

As an outgrowth of European-US imperialism, the agricultural systems of the Global South had, and to some extent retain, a dual structure. Vast expanses of land are devoted to export production, that which initially fed the Industrial Revolution with raw materials and an abundance of food to maintain their cheap food policies. However, interspersed in those vast estates are millions of small-scale farmers who produce both for their families and the local (and sometimes international) markets. With a few

exceptions, like shade-grown coffee and cacao in the Americas, the export sector (and their allies) is now heavily capitalized and frequently labour-intensive. The small farming families constitute a convenient source of the labour so necessary for that export sector. In what has been termed a dual economy, labourers come from the farming sector and retain their flexibility by retaining ties to that farming sector. These ties become important when, invariably, the jobs in the export sector disappear and workers return to the family farm to become farmers again. Increasingly, the ties to the farming sector are cut, forcing fired workers either to transform unused land into new farms, or to move to the cities. This has resulted in a large standing crop of landless poor, some in the cities, some wandering the countryside filling temporary agricultural positions, and some migrating to the developed world. This distancing of workers from the consumption society is extremely efficient for the export sector, unconcerned as it is about local consumer demand, and thus able to drive wages down to minimum levels.

Responses of the subaltern to this arrangement are frequently brutally repressed. Nevertheless, they remain common and sometimes reach national proportions, as in Mexico in the late 1930s, Guatemala in the early 1950s, Cuba in 1959, Nicaragua/El Salvador in the 1980s and the Zapatistas in Mexico in the mid-1990s.

What is new today, is a growing political consciousness about the origin and maintenance of the condition of the small farming sector in the Global South. Propelled by a rapidly diffused analysis of the neo-liberal agenda, farmers the world over are rejecting the economic model implicit in the conventional agricultural system. Most significant is the development of the idea of food sovereignty by the umbrella organization Via Campesina⁴⁵ (Figure 6.1).

A UN goal for a long time, the concept of food security has been a centrepiece of human rights advocates at a global level. In a world of plenty, goes the argument, we ought to be past the time in history when people must go to bed hungry, and socio-political arrangements ought to be organized in such a way that a basic diet is available to all. So-called 'food activists' have been pushing for the acceptance of this idea as a basic human right for many years. Indeed, the right to food is now recognized in Article 11 of the UN's International Covenant on Economic, Social and Cultural Rights, which has been signed by many countries. What is new today is the conjoining of the rights of people to consume food to the rights of people to produce their own food, a synthesis that Via Campesina refers to as 'food sovereignty'.⁴⁶

Food sovereignty has become a rallying cry for rural social movements across the world and fits snugly with previous political ideas and action associated with land tenure. Those landless people, so the argument goes, are landless because of the underlying political structure that favours the concentration of land in the hands of the wealthy who, frequently, do not even use it 'productively', but rather retain it as a capital investment



Figure 6.1 *Women members of the Via Campesina participating at the World Social Forum in Brazil in 2005*

Note: Inset is the logo of the Via Campesina.

Source: Grassroots International

or speculation. In a variety of political venues, from local courts to land invasions (or as they are sometimes referred to, land rescues), to international protests, this new movement has taken on something of a spontaneous and surprisingly resilient form, from farmers mainly in Asia and Latin America, with participation of small-scale farmers from all over the world, including the developed countries.⁴⁷

In addition to the human rights issues uncovered and publicized by these new rural social movements, a key political conjunction has been between the movements for food sovereignty and those for alternative agriculture. Via Campesina, for example, talks extensively on its web page about sustainability, ecologically based production and conservation. The image that some conservationists in the Global North have of peasants overpopulating the land and consequently destroying biodiversity, is supported less each year, as the popular movements make political headway. That most conservation programmes now acknowledge poverty reduction as part of any viable conservation programme is perhaps at least partly a consequence of the political agitation generated by these new rural social movements. These movements are beginning to exert important

influence even in high-level intergovernmental assessments. For example, the International Assessment on Agricultural Knowledge, Science and Technology (IAASTD),⁴⁸ a UN and World Bank-sponsored assessment of the role of agriculture in the reduction of poverty and hunger and towards a more equitable and sustainable development, called for a paradigmatic shift away from conventional large-scale agriculture, emphasized the role of small-scale farmers and local or indigenous knowledge, and (at least in the Latin American and Caribbean regional report) presented options for achieving food sovereignty⁴⁹ (Figure 6.2).



Figure 6.2 Policy options for achieving food sovereignty recommended by the Summary for Decision Makers in the IAASTD's Latin America and Caribbean Regional Report

Source: Authors' modification from Rosset, 2008

Returning to the specific theme of this book, of the two remnants of European imperialism in the matrix of today's tropical fragmented habitats, it is perhaps only rhetorical to ask which is likely to create a high-quality matrix. Large-scale production of bananas, sugar cane, tea, technified coffee and cacao, soybeans, cotton, pastures, and others are notorious for their environmental unfriendliness. Small-scale farmers with their usually

mixed farming techniques applying, either by conviction or necessity, organic-like and environment-friendly techniques, square far more obviously with the emerging concept of a high-quality matrix.

The vision of a matrix composed of small-scale ecological agriculturalists may seem utopian to some. But real-world examples do exist, demonstrating that with proper political will such a vision can dramatically improve the lives of poor and middle-class people even as it acts to create the high-quality matrix we seek for conservation purposes. Recall the example of the farming family in Kerala, India, cited in Chapter 5 – farming only one and a half hectares with completely organic methods, producing a diversity of products both for home consumption and sale in local markets. The conditions of that family, especially given India's position in the Global South, are remarkable. A two-storey house that would be regarded as middle class even in the developed world, a car, a motorbike, a satellite dish – all the amenities we normally associate with a middle-class existence, with well-dressed children receiving high-quality education and complete access to health care. The issue is not so much the productivity of the land, but the style of agriculture and, of course, the option for the poor that the state of Kerala had long ago developed as a priority. The vision is not utopian. However, it will require the revitalization of rural areas in ways that will create conditions for a dignified livelihood for rural people. We are not idealizing rural poverty or ignoring the harsh life of the rural poor. On the contrary, we are proposing a change in the social, political and economic structures that recognizes the contributions of small-scale farmers to food production and biodiversity conservation, and properly rewards those who put food on our tables. Furthermore, we think that it is important to reconstruct rural communities in ways that make it attractive to young people by providing economic, cultural, social and educational opportunities for them.

An additional fact is worth considering associated with agricultural productivity in the Global South. Contrary to what is frequently an unstated assumption that larger farms tend to be more efficient, an analysis of 15 underdeveloped countries found that production (or productivity – amount produced per unit area) declined as farm size increased,⁵⁰ and another study found the same thing in the developed world (in the US).⁵¹ That is, smaller farms tend to be more efficient than larger ones, in terms of producing agricultural products (though not necessarily profit). It is not difficult to see why this is the case. Small farms, especially very small ones, tend to be managed 'ecologically', at least in the sense that the farmer usually knows his or her farm very well, understanding the ecological peculiarities of each and every corner of it. Contrary to the industrial mantra that larger sizes mean more efficiency, when ecology is brought into the equation, the reverse seems to be the case. And, of course, the smaller the farm, in general, the more likely it is to be more ecologically managed.

PUTTING THE THREE ARGUMENTS TOGETHER

New knowledge about the science of ecology; current debates about agriculture (especially in the tropics); and new and powerful rural social movements with a global reach and with strong environmental concerns – these three general tendencies intersect to result in a new paradigm of environmental conservation as applied to biodiversity. Ecological science has converged on the idea that populations exist in a spatially complex context and that at any one point in space any population will experience a local extinction at some time or another, if enough time passes. Key to the maintenance of biodiversity, probably ever since life became complex some 500 million years ago, is the balance of migration to new sites and local extinction. Since there is not much we can do about local extinctions (they have been happening as a matter of course since life became complex), the only potential interventions that make sense must be with the migration rate.

Political realities are such that most biodiversity is located in the tropics, most of which exists in a highly fragmented state, the matrix of which consists mainly of different forms of agriculture. In conjunction with what we know now about how populations behave in Nature, it is not within the fragments of remaining natural habitats on which we should focus, but rather on the matrix within which those fragments occur. Inter-fragment migration is key, and a high-quality matrix is key for that. Farming practices that emphasize concepts such as sustainability and ecological planning are most likely to produce that high-quality matrix.

Finally, the new social movements that have arisen throughout the tropics represent a challenge to the large-scale, monocultural, chemical (and now transgenic)-based agriculture that has developed since World War II. The agenda of these new social movements includes precisely the sorts of agricultural practices that have come to be associated with a high-quality matrix. Furthermore, the extension of the popular human rights initiative of food security to the more inclusive and transformative idea of food sovereignty, incorporates ecological agriculture along with conservation as key political goals. The new paradigm lies at the intersection of these three realities.

To be sure, the paradigm we describe is ‘new’, and it is likely that most traditional conservationists will recoil against it, at least initially. It is a paradigm that gives preference to more progressive political struggles for land rights over traditional lobbying for set-aside reserves of inviolate nature. In particular, as discussed fully in Chapter 4, the traditional conservation agenda has important foundational elements in a primitive Malthusian formulation, even if not explicitly stated as such. The underlying assumption, frequently left unsaid but strongly implied, is that there is a direct relationship between the amount of land devoted to food production and the size of the population: if there are x people and each requires food from n hectares of land, xn is the number of hectares

required for the population. The problem is thus conceived of as a zero-sum game in which every piece of land devoted to agriculture cannot be devoted to biodiversity conservation, with the strong implication that if there were fewer people, or more intensive agriculture producing more food, there would automatically be less land devoted to agriculture, and therefore more biodiversity conservation. With this fundamental framing, conservation goals frequently include population control, increasing agricultural production through the intensification of agriculture on land that is already under production, and higher vigilance of areas under 'protected' status.⁵² The framework that leads us to the new paradigm is distinctly different, recognizing the well-accepted conclusion that it is not the amount of land in production that determines whether a family has adequate food, but rather the amount of money available to buy food. The irony that the world produces more than enough food and yet hundreds of millions of people go to bed hungry every night is a result of socio-political arrangements, not a simple 'land times population' equation.

Having subtle roots in Malthusian assumptions is certainly a barrier to understanding the complex interplay among land, society and conservation. However, perhaps the most troubling aspect of the conventional conservation agenda is the failure to realize that not all agriculture has the same effect on biodiversity. The crucial aspects of a high-quality matrix will tend to be eroded with more agricultural intensification, and the landscape effects are likely to be negative overall. From our point of view, this is an especially ironic lacuna in conventional conservation thinking.

Finally, the perceived rationality of building fences and maintaining armed guards, metaphorically speaking, is largely derived from a sense of frustration that most reserve areas, especially in the tropics, are under continuing threat from a variety of elements, from poachers to settlers. That perception is certainly true. However, much as the wall between the US and Mexico is not going to keep immigrants from seeking a better life in the US, fences and armed guards are not going to stop people who are desperate to feed their families and are in search of a better life. This is not to say that corruption and greed are not involved in many cases, but for the most part corrupt officials and greedy entrepreneurs are likely to have as many lawyers and guns as the conservationists and holding back poor people who need to feed their families will only create desperation.

As a counter to the traditional conservationist agenda, the new conservation paradigm avoids many of the usual pitfalls by recognizing what is, we argue, a set of real, on-the-ground contingencies:

- 1 Advances in ecological research, both theoretical and empirical, show that local extinctions are natural and unavoidable.
- 2 Conservation of biodiversity must thus concentrate on migration rates rather than extinction rates.
- 3 The tropics, where most of the world's biodiversity is located, are highly fragmented at the present time, and are likely to be more so in the future.

- 4 Migration rates among fragments are mainly determined by the kind of agro-ecosystem in the matrix.
- 5 Small-scale farmers and agro-ecological methods are most likely to promote a high-quality matrix.
- 6 The political struggle for local food sovereignty is part of the struggle to conserve biodiversity.

This new paradigm carries with it normative consequences. It suggests that conservation activities need to interact with the rural masses and their social movements,⁵³ more than with wealthy donors. Indeed, we suggest that these new rural social movements hold the key to real biodiversity conservation. Joining the worldwide struggle of millions of small-scale farmers clamouring for food sovereignty is more likely to yield long-term biodiversity benefits than buying a patch of so-called 'pristine' forest.

NOTES

- 1 Condit et al (2002).
- 2 Skelly et al (1999).
- 3 Pollinators, for example, are attracted to resource patches made by the plants that produce flowers (Heinrich, 1975).
- 4 Ferraz et al (2003).
- 5 Hubbell (2001).
- 6 Western and Pearl (1989).
- 7 McNeely and Scherr (2003).
- 8 e.g. Terborgh (2004).
- 9 Giller et al (1997); Vandermeer et al (2002b).
- 10 Perfecto et al (1996); Giller et al (1997); Donald et al (2001, 2004); Vandermeer et al (2002b); Perfecto et al (2003); Wickaramasinghe et al (2004); Tschardt et al (2005); Philpott et al (2006).
- 11 Wilson (1986).
- 12 Lecointre and Le Guyader (2006). The number of kingdoms varies with the sources but new phylogenetic studies have dramatically increased the number of kingdoms from the previous five.
- 13 Thrupp (1988).
- 14 Hayes et al (2005).
- 15 Relyea (2005b).
- 16 Smith and Oehme (1992).
- 17 Werner et al (2007).
- 18 Kaimowitz and Smith (2001); Trigo and Cap (2003); Pengue (2005).
- 19 Borlaug (1987, 1997); Waggoner (1994); Waggoner et al (1996); Cassman (1999); Trewavas (2002).
- 20 Balmford et al (2005); Green et al (2005).
- 21 Wiersum (1986); Barraclough and Ghimire (1995); Foster et al (1999); Angelsen and Kaimowitz (2001b); Lee and Barrett (2001); Morton et al (2006).
- 22 Kaimowitz and Smith (2001); Wright and Wolford (2003); Schelhas and Sánchez-Azofeifa (2007).
- 23 Simon and Blume (1994).

- 24 Perfecto et al (2005).
- 25 Angelsen and Kaimowitz (2001a).
- 26 Angelsen and Kaimowitz (2001b).
- 27 Stanhill (1990); Pretty et al (2003); Halberg et al (2005).
- 28 Lockerez et al (1981); Mäder et al (2002); Trewavas (2004).
- 29 Badgley et al (2007).
- 30 For a meta-analysis, see Bengtsson et al (2005).
- 31 Jonsen et al (2001); White et al (2002); Bender and Fahrig (2005); Donald and Evans (2006); Vaughan et al (2007).
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