Biodiversity, Nature and Food Security: A Global Perspective

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KEYNOTE PRESENTATION

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Biodiversity is the basis for agriculture and for a sustainable future. More than 1.9 million living species have been described; millions more have gone extinct, including major branches of the tree of life. The distribution of this biological diversity is variable in space and time, although it is becoming more homogeneous as a result of globalisation. Only a few hundred species of plants and animals have been domesticated over the past 10 000 years, yet they are essential for the livelihoods of people worldwide. New tools are giving us insights into the origins of agriculture, as well as opening new possibilities for using and changing the genetic diversity of these crops and races. This can have a major impact on the well-being of present and future generations. Agriculture is also having major impacts on natural ecosystems. An estimated 25% of terrestrial ecosystems have been transformed into production systems, mostly in the past 50 years. Habitat loss and fragmentation, pollution and invasions are some of the impacts. Climate change is likely to have additional impacts that will alter the distribution and abundance of biodiversity, as well as the interactions among species. It is time to bring together knowledge from biodiversity science and agriculture through a whole-system approach. A better understanding of the diversity, distribution, evolution and ecology of life is essential for a sustainable future. It can also open new avenues for agriculture and food security.

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Introduction

Our home is a little blue planet that is 4.56 billion years old; where we know there has been life for over three billion years. We share it with more than six billion people and more than ten million other species of plants, animals and micro-organisms. We know this thanks to the work of many generations of scientists who have explored this planet to understand nature and our place in it. Many of their findings have been gathered in extraordinary collections like that of the National Museum of Natural History in Washington. There are many kinds of collections—not only natural history collections but seed banks, germplasm and microbial collections. Some of the species in these collections are essential for agriculture and for the livelihoods and the quality of life of people all over the world.

It is important to remember that we are just one of many species: a very particular species in terms of our history and our impacts, but also our understanding of the past, present and future. My perspective is that of a biologist and a biodiversity scientist, and therefore different from that of many people in the audience. This different viewpoint, however, is precisely the reason for this kind of conference, providing as it does opportunity for dialogue across disciplines. I myself look forward to learning more about agriculture in the course of the conference.

I will focus on four main topics:

- the distribution of diversity—what we know and what we don't know
- the relationships between humans and this biodiversity
- some of the main drivers of change in diversity and what we understand
- ecosystem services and their importance to food security, and some choices and options for the future.

Biodiversity

We have described about 1.9 million living species of animals, plants and micro-organisms in the planet today; more than 50% of those are insects, and only a few tens of thousands are vertebrates like ourselves (Chapman 2009). But we've described only 15–20% of all extant biodiversity, a small proportion of the perhaps 10 million species out there (Fig. 1). Professor Hopper [page 92] mentioned that about 2000 new species of plants are being described every year, and about 35 000 species new for science are being described annually across various taxonomic groups. Fortunately, most of this information is freely available through resources like the *Encyclopedia of Life* (www.eol.org) . It is obvious that a lot of work lies ahead to understand global biodiversity—and understanding this diversity is fundamental to the choices that we need to make as a society.

We also know that biological diversity is not distributed uniformly around the planet. Tropical countries tend to have a very high diversity. Most terrestrial diversity is found in the New World and South-East Asian tropics. The pattern of marine diversity is somewhat different; the bulk is found in the area just north of here—the Coral Triangle and the whole region of South-East Asia. We also know is that the distribution has been dramatically different over time—the fossil record provides windows into the past. Fossil trilobites that lived 420 million years ago in present-day Morocco remind us that very different groups of organisms have previously dominated the planet. Fossil records indicate that more than 95% of all life on earth has already gone extinct (Erwin 2006).

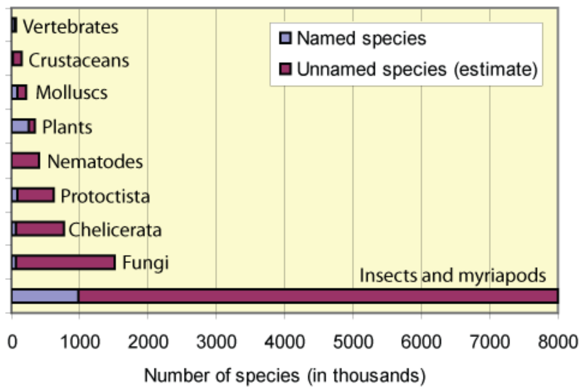

Figure 1. Some 1.9 million living species have been described

This poses a real challenge for those of us interested in science and environmental issues. We have to recognise that extinction is part of the natural history of this planet—the key question is whether our actions and activities are changing that rate of extinction. I use the word 'rate' because that is the essential element here: it is not just what is going extinct, but how fast and where it is going extinct. There is clear evidence that we as humans are accelerating the rate of extinction (Millennium Ecosystem Assessment 2005).

Humans and biodiversity

To start drawing the connection between biodiversity and human wellbeing, I want to take you back to my backyard. I grew up in Colombia in South America, and as a biologist I spent many months in the field studying tropical rain forests. These forests include extraordinary rock formations known as Tepuis, that are like islands over a sea of forests. Halfway up them you may find pictographs that were made by humans a few thousand of years ago. These pictographs are important and powerful reminders that our ancestors have always interacted with their environment, with different elements like the fish and mammals represented. Over thousands of years we have been hunter-gatherers who have depended on the interaction with biodiversity for food, clothing and shelter. We would not be here if it was not for that biodiversity. Indigenous people all over the world have selected particular elements of biological diversity and shaped it for their livelihoods, as in this case with capsicum and chili pepper.

We now have new tools at our disposal in science that are changing our understanding of the origins of agriculture in the world. Just to give you one example, one of my colleagues at the Smithsonian, Dolores Piperno, has been studying phytoliths—tiny silicon grains that are found inside the tissues of the leaves of plants. The phytoliths of chili peppers, corn and other crops, and archaeological remains, reveal that chillies were domesticated more than 6000 years ago by indigenous peoples in the Amazonian Basin (Piperno and Flannery 2001). For a handful of crops our influence has been dramatic; they have become incredibly important for our livelihoods. Only 12 crops probably feed about 80% of the people in the world. Figure 2 illustrates diversity in maize from the highlands of Ecuador. It is important to recognise that humans have selected many of the characteristics, now evident, from the rich variation present in undomesticated wild populations (Smith 2002). Under our influence this diversity has provided many traits and characteristic that are important in sustaining the livelihoods of people not only in local communities but globally.

One of the fundamental tasks in biodiversity work, in addition to documenting relevant diversity, is preserving it in genetic banks and using that diversity to improve the productivity of crops—the yields, the nutritional value—and thanks to that we have improved the lives of people. It is not enough, however, to preserve the genetic diversity of crops and their wild relatives alone. It is fundamental to understand the natural history behind these, and the interactions between relatives and the biodiversity around them.

Leaf-cutter ants from the rainforests of Panama were some of the first farmers: they collect leaves, use them to feed fungi and feed on the fungi to grow their colonies. This is an example of the co-evolution between plants and animals of which there have been many instances over millions of years. If we really want to understand the forces that are shaping nature, we need to understand how those interactions have happened in the past. We're barely scratching the surface of what we need to know.

Figure 2. Diversity in maize, Ecuador

I will give just two examples. If you go into a rainforest in Panama and look closely inside the leaves of plants you find endophytic fungi—fungi that are found only growing inside the leaves of some trees, and in a single species of crop, cocoa, *Theobroma cacao*. In one locality we have discovered and described more than 600 different species of fungal endophytes (Arnold 2001). We are starting to understand that the presence of these endophytes is fundamental to the lives of some of these plants: to their resistance to disease and to growth rates (Arnold 2007). We know of similar cases for some of agricultural crops. An incredible diversity of micro-organisms is shaping the growth and the natural history of life around us.

The other example, which is probably more familiar to many people working in agriculture, is that of insects—in this case parasitic wasps. These wasps have been very important for biological control over many decades. The remarkable thing is their mind-boggling diversity: we estimate that there are between eight and ten species of parasitic wasp for every single species of host insect. As we have described about 800 000 species of insects on the planet, the abundance of their parasites really begins to give a sense of incredible diversity. To what extent some of these species are specific, how they could have evolved and how they are related is really important in understanding not only genetic diversity but the interactions between multiple organisms. It can also have a major impact on agricultural systems.

Today, with the advent of new technologies in molecular biology we can probe deep into the genomes of the various crops to better understand their genetic diversity. We can reconstruct the evolutionary history of life on earth. We are opening the doors to being able to move genetic material between different kinds of crops and to use it in ways that can have major impacts on food security.

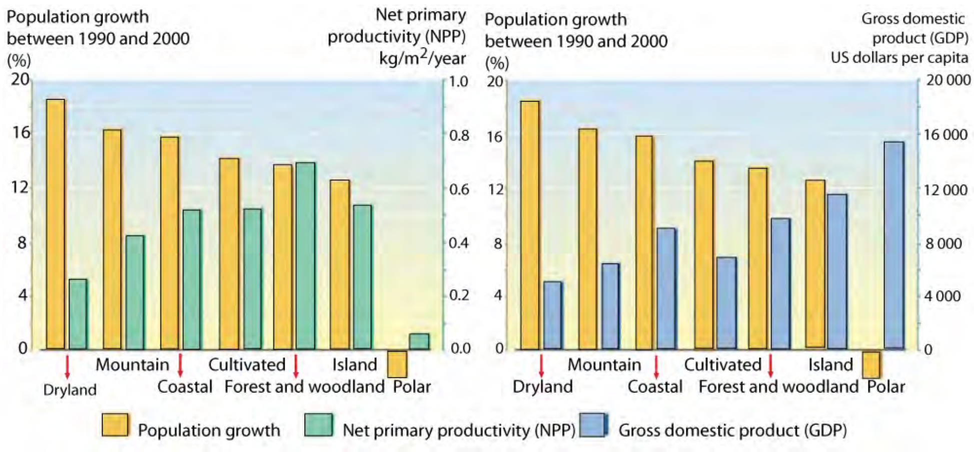

Figure 3. Population growth, primary productivity and gross domestic product in diverse environments. (Source: Millennium Ecosystem Assessment—Running *et al.* 2004)

Our impact as humans on the planet

There have been dramatic changes in this planet over the last 50 years. Between 1960 and 2000 the global population has increased from three billion to six billion people, more than doubling. Over that same period economic activity, measured as GDP, has increased six-fold and food production globally has increased 2½ times: that is, growth in food production has outpaced that of population, largely as a result of the green revolution. During that same time the demand for water has doubled and the amount of water impounded by dams has quadrupled, with major consequences for the flow of water in some aquatic ecosystems. Similarly the flows of phosphorous and nitrogen have more than tripled, largely as the result of the use of fertilisers for agriculture; this has had dramatic consequences for the ecology of some aquatic ecosystems. So our footprint as humans has dramatically increased and changed in the last 50 years—just two generations (Millennium Ecosystem Assessment 2005).

Where is this happening on the planet? We are not uniformly distributed; the bulk of people are found in Asia, China, India, the coastlines of a few of the continents, and Europe of course. This means that there are certain areas where there are particular challenges to food security. One way to look at this is to analyse the fraction of net primary productivity that is being used by people. Primary productivity is a good measure of how much energy is available for use by people. In some regions we are taking out more productivity than is actually being produced by the natural ecosystems. The biggest challenges are in places like China, India and parts of the Middle East. Australia is doing relatively well. The solution to many of these challenges directly relates to investment, especially in agriculture. The impact is very different in different ecosystems and biomes. The left half of Figure 3 shows the percent population growth by different kinds of ecosystem: dryland, mountains, coastal ecosystems and so on, and the net primary productivity. The real crises that is looming is to be found in dryland ecosystems—areas that have the slowest growth in net primary productivity and the highest growth in population (and, on the right half of the figure, gross domestic product per capita).

The work of the Food and Agriculture Organization (2010) highlights the problem of food insecurity across the globe. Figure 4 provides a global picture of the course of the response of agriculture to our investment in productivity from 1961 to 2003–2004. Total food production has increased by about 150%, and production per

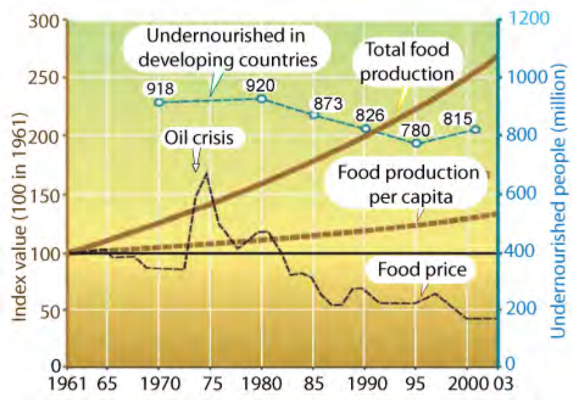

Figure 4. Food production and nourishment (Source: FAOSTATS, SOFI)

capita has also increased. Food price tended to go down, although there was a spike in the 1970s and another (not shown on the graph) in 2008–2009. The number (and more so the fraction) of people who are undernourished has fallen. So we have made dramatic progress in accommodating the doubling of the human population. Many people, however, still face huge challenges to their livelihoods, and more recent data from FAO (Fig. 5) is very disturbing Although there was a positive tendency to reduce the number of people worldwide who were malnourished, recent events—the economic crises and spikes in food prices—are increasing the number of people that are considered to be malnourished right now to over one billion. Most of those people are found in Asia (Fig. 6). It is important that the measures and the choices that we make are addressing some of these globally important areas.

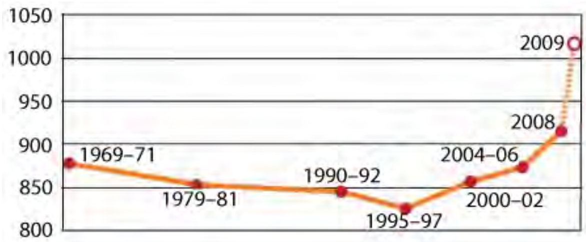

Figure 5. Learning from the past: the number of under-nourished people in the world (Source: FAO)

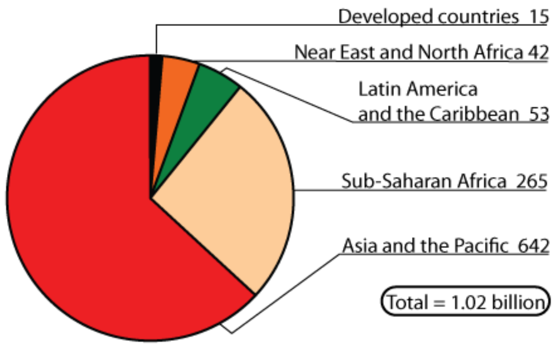

Figure 6. Under-nourishment in 2009, by region (millions) (Source: FAO)

Drivers of biodiversity change

There are five main drivers of change in biodiversity: habitat transformation, over-exploitation (which is a huge issue in marine systems), invasive species, pollution and climate change. Not all are equally important across ecosystems (Fig. 7). For example, in island ecosystems the single biggest problem is invasive species; in some mountain ecosystem climate change will be very significant. Understanding the importance of these drivers is fundamental to looking for and examining response options.

We estimate that 25% of the natural terrestrial ecosystems of the planet have been transformed into agricultural production systems (Millennium Ecosystem Assessment 2005). I expected this figure to be larger; its magnitude has to do with the definition of what’s considered transformed. If we compare these changes with the distribution of the biomes and ecosystems on the planet, we can start seeing where the biggest impacts have taken place. Figure 8 shows the various kinds of ecosystems and the fraction of the original cover that was transformed by 1950, between 1950 and 2000, and the projection for the next 50 years. The temperate forest was one of the ecosystems hardest-hit historically, but the biggest changes in future will be in some tropical rainfor-

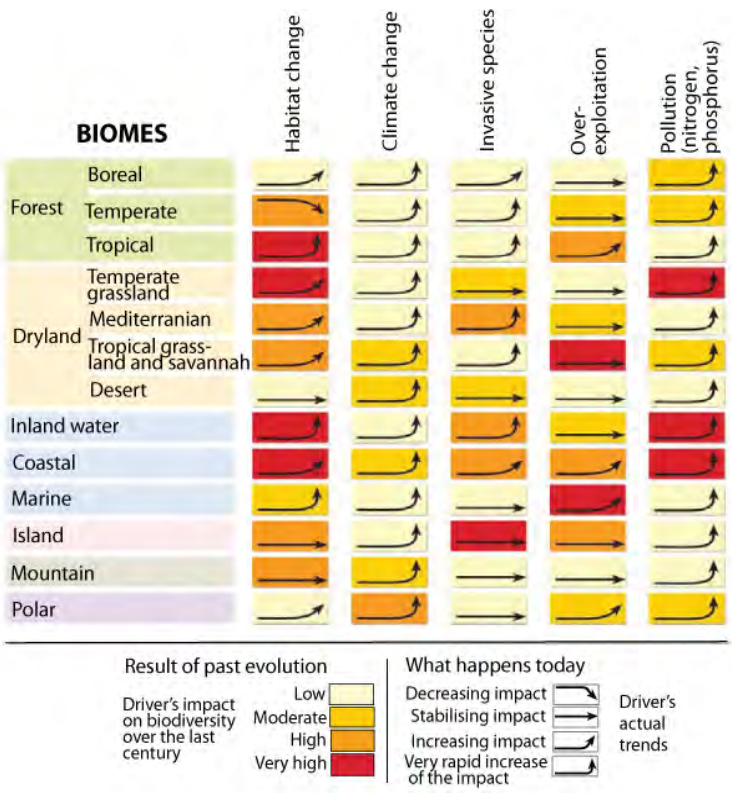

Figure 7. Drivers of change in biodiversity (Source: Millennium Assessment 2005)

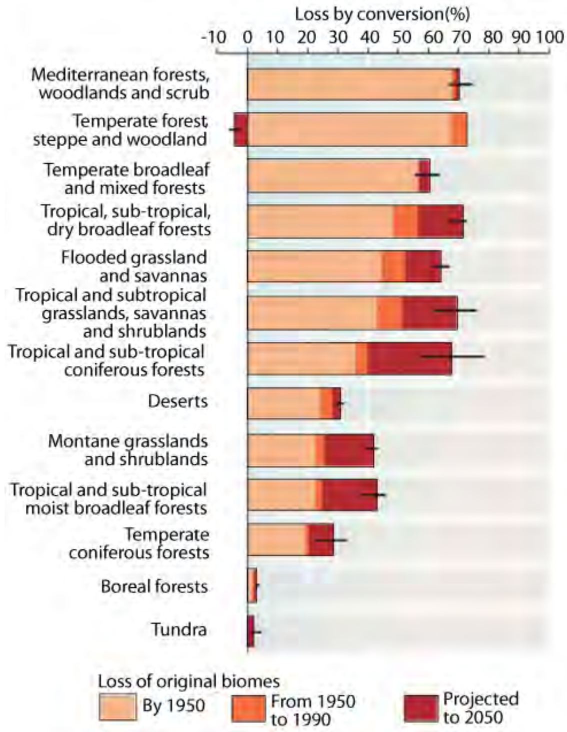

Figure 8. The temporal course of loss of major ecosystems

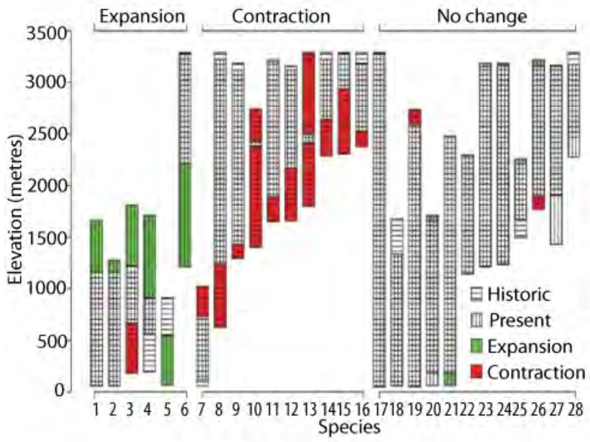

Figure 9. Change in altitudinal distribution of 28 small mammals over 100 years (Source: Moritz *et al.* 2008)

ests. A positive exception to the overall trend is that we project that there will be a net gain of temperate forest cover of about 5% in the next 50 years.

Another major driver of change that is often overlooked is the issue of invasive species. People in agriculture know this, but many other people don't. It is a huge problem; not only for crops but for native biological diversity. Many of the areas most affected by invasive species are directly related to global trade routes. In a globally interconnected world with increasing trade and other activity, this is going to get only worse. Not surprisingly areas like the Mediterranean are some of the hardest hit, but places like Australia and South America are becoming increasingly important for coastal marine invasives.

Climate has changed many times in the history of this planet. There have been moments in the past where the CO_2 levels have been higher than in any of the projected scenarios that we are looking at now. Climate change has shaped the evolution of diversity of life on earth. There is no doubt, however, that the rate of change has dramatically increased in the last 50–100 years and that this acceleration is directly related to human activities. We are starting to get data showing the impact that this is having on biological diversity. One example is a study by Craig Moritz in the mountains in California, showing the changes over 100 years in the altitudinal distribution of 28 small mammal species (Fig. 9). These data show that, in response to climate change, most species are moving up the mountains and their ranges are contracting. The number of species is not changing dramatically, but climate change is starting to have a real effect on the distribution of and the interaction amongst some of these species (Moritz *et al.* 2008).

Ecosystem services and food security

The interaction between biodiversity and ecosystem services and human wellbeing is fundamental. Ecosystem services are the services that we derive as humans from ecosystems. We readily think about 'provisioning services' such as agriculture or fisheries that provide food. What are less obvious are the regulating services like climate, water, nutrient cycling, or even the cultural and spiritual values (including recreation) relating to these ecosystems. Historically we have focused most attention of provisioning services at the expense of regulating, cultural and spiritual services. As most economists focus on the services that are traded through markets, those without a market value present a problem, although they may determine the livelihoods and wellbeing of people. Figure 10 is another graph from the Millennium Ecosystem Assessment (2005) portraying the various kinds of ecosystem services: although we are focusing on food now, we have to take a much broader look at other services. Without water, nutrient cycling and climate regulation

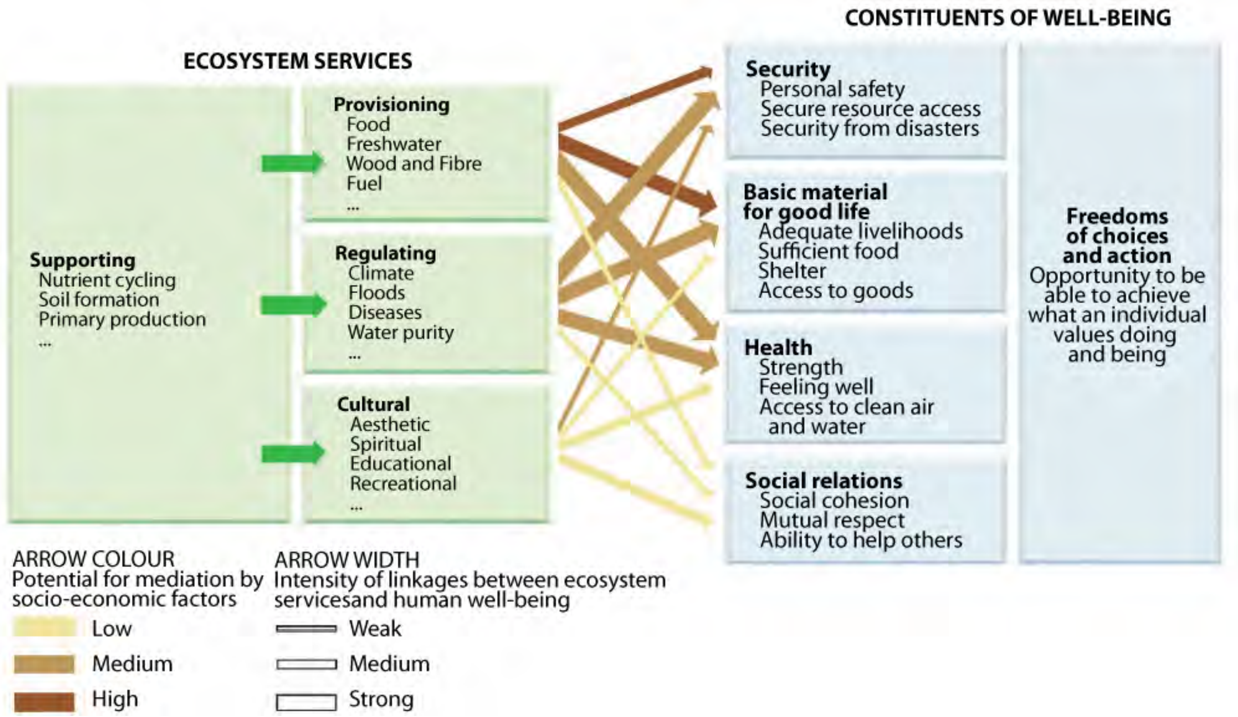

Figure 10. Consequences of ecosystem change for human well-being (Source: Millennium Ecosystem Assessment 2005)

there will be no agriculture. Human wellbeing requires more than food security and access to food; it includes health and social relations. We have been focusing on interactions between food and food safety and not necessarily taking a broader look at other dimensions of human well-being.

Response options

The Millennium Ecosystem Assessment (2005) also evaluated a variety of response options, which fall into five broad categories: (1) institutional responses, such as the establishment of protected areas; (2) economic responses including access to markets and removal of subsidies; (3) social and behavioural responses that directly relate to the choices that we make in society—where education and public awareness are very important; (4)technological responses, like optimising water use efficiency, are extremely important in areas like agriculture; and (5) access to the knowledge that we have gathered around the world.

The choices that we make as a society are critical. Figure 11 depicts four future scenarios that result from combinations of global or regional views and either proactive or reactive responses (Millennium Ecosystem Assessment 2005). These options, which have been characterised by brief labels in the figure, are of course extreme, and the likely answer is a combination of the four. The important point I want to make is the choices that we make as a society will have profound impacts on biodiversity and food security in the next 50 years. Three more graphs (Figs 12, 13 and 14) illustrate that point. All the scenarios suggest that population is going to increase dramatically by at least another couple of billion people in the next

Figure 11. Future scenarios

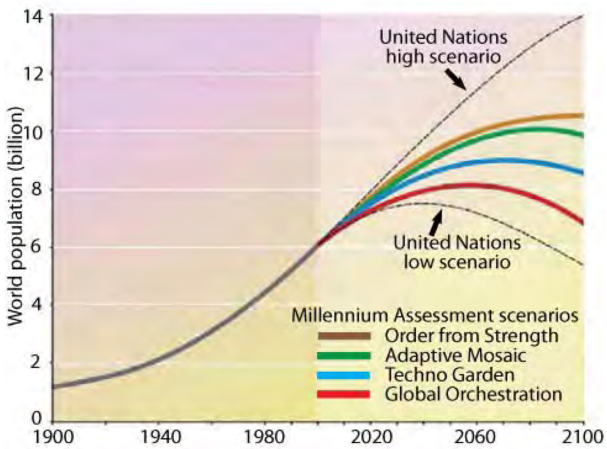

Figure 12. Changes in population. By 2050, the population is projected to grow to 8–10 billion and per-capita income to increase two- to fourfold.

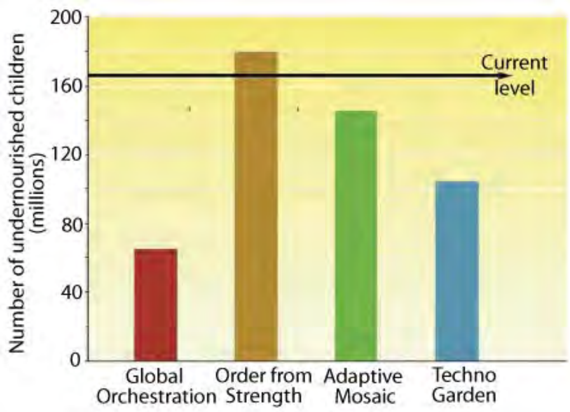

Figure 13. The number of undernourished children is expected to be influenced by the population scenario (Source: Millennium Ecosystem Assessment)

50 years (Fig. 12). But if you look a hundred years on, the difference between them is huge; some scenarios suggest we will be back to about 6 billion people 100 years from now. Some of them suggest that the number will increase to over 9 billion people—a lot of mouths to feed, with major implications for food security. Not only is how many people we have important, but how many don't have access to good food and good food security.

The good news is that under most scenarios the number of undernourished children will drop. The important thing is that the differences are tremendous, and some of the scenarios will have a much greater impact on food security globally than others. Global orchestration, focusing on a multilateral world readily transferring knowledge, food, food security and trade will probably be the single best one for improving food security, whereas others will actually potentially increase the number of malnourished children. These are choices that we need to make as a society.

The different scenarios will have very different consequences for the three main categories of services: provisioning services like agriculture, regulating services like water and nutrient cycling, and cultural services like recreation. Technology—extremely important in agriculture—will have a major effect by improving access to provisioning and regulatory services, but it will do so at

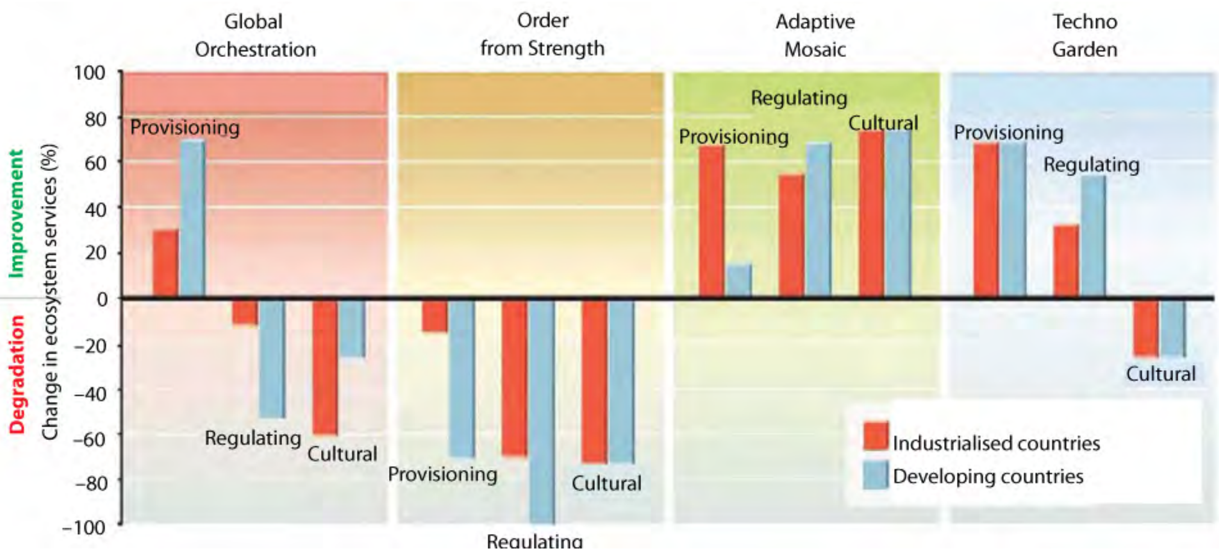

Figure 14. Changes that may accompany future scenarios (Source: Millennium Ecosystem Assessment 2005)

the expense of cultural services because technology will drive a lot of local practices and adaptations out of traditional knowledge.

The answer is going to be a combination of those five categories of responses options. The choices we make will have a dramatic impact on the lives of people because we are living in a constantly changing planet. As a species have already had a tremendous impact—like no other species before—and the choices that we are now making will shape the future.

Our agriculture and food security will be intimately dependent on biodiversity not only for genetic material. If we want to improve food security we have to base it on a better understanding of biodiversity and ecosystem services. Choices that we make related to agriculture and food security will also have a dramatic impact on the future distribution of biological diversity.

A conference such as this one brings together these two perspectives. A country like Australia, being a player in the region and in the world, can have a very important role in the future, helping to shape a better world where we achieve a balance between biodiversity and food security.

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