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**Sir John Crawford Memorial Address:  
Plant Diversity at the Turning Point**

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## Sir John Crawford Memorial Address

# Plant Diversity at the Turning Point

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The world aspires to sustainable healthy living for all. This ambition is challenged by accelerating global change, fuelled directly by entrenched patterns of land and water use and loss of biodiversity, combined with rising consumption and ongoing population growth. We can and must improve levels of agricultural productivity to feed the world. At the same time, the hope of a continuing 'green revolution' as future salvation focussed on a few mainstream crops seems increasingly unlikely without new land and water ethics, economics, and political and financial systems that value social and natural capital as much as present systems focus on financial goals. We are at a global turning point, comparable to that when slavery was abolished. Plant diversity has never been more important than now to help with solutions towards sustainable livelihoods. This presentation will touch upon global plant diversity patterns, ongoing scientific discovery, and strategies that have helped and will help towards humans living with and sustainably using biodiversity.

Professor Steve Hopper is a conservation biologist and the 14th Director of the Royal Botanic Gardens, Kew. He holds Visiting Professorships at the University of Reading, The University of Western Australia and at Kings Park and Botanic Garden in Perth, and is a Fellow of the Linnean Society and a Corresponding Member of the Botanical Society of America. He was awarded the Nancy T. Burbidge Memorial Medal from the Australian Systematic Botany Society in 2008 and an honorary Doctor of Science degree from the University of Western Australia in 2010. He has led the development of a collaborative forward 10 Year Breathing Planet Programme for Kew and its global partners that seeks plant diversity solutions towards sustainable living and a reasonable quality of life.

### Introduction

It's been my pleasure and privilege to be the director of the Royal Botanic Gardens, Kew for four years, the first non-British-born person to hold that post. Some might say that Kew's Trustees took a bit of a risk in appointing a foreign national to the job. But we do live in a global village—every city, every country, the world has changed dramatically from when I was a university student just 30 years ago. And I hope that applying new international thinking to old vibrant organisations in rapidly changing times can be beneficial.

In this context, I would like to put some propositions to you to provoke thought that I hope will be of benefit to the theme of the conference.

Firstly, I propose that global change is evident, including global warming and the loss of biodiversity, associated with and accelerated by human action—especially unsustainable use of land and water on parts of the planet.

Secondly, we are at a turning point—at no other point in history has plant diversity been more important to people than this time.

Thirdly, it is a time to rethink. We have to deliver on a new relationship between plants and people and this will involve, in part at least, scaling up plant diversity science and using plants sustainably across mainstream human livelihoods.

Fourthly, the next decade is critical. You only have to read the literature on global warming—Lord Stern's (2006) report on the economics of climate change—to understand that no longer can we think bad things are going to happen three, four or five decades away. It's real, it's with us now and it's our responsibility to take action, not

in a rushed or unthinking way, but in a measured way and with a sense of urgency.

Lastly there is a message of hope. None of the things we have to do in order to pull through the challenges the world faces are particularly new. Many of them are already being done or have been done before. But can we achieve sustainable living and livelihoods and an adequate quality of life for humanity, in a reasonably timely fashion for most people on the planet? That question obviously goes into the arenas of economics, of politics, of finance—beyond any insights I can give you as a biologist—but the ultimate take-home message is ‘we are all in this together’, and new partnerships and new ways of collaborating are essential. What I can offer as a practicing conservation biologist are some insights on the issues of importance if we are to live sustainably with biodiversity in the future, conserving nature’s riches and better integrating their use into human livelihoods.

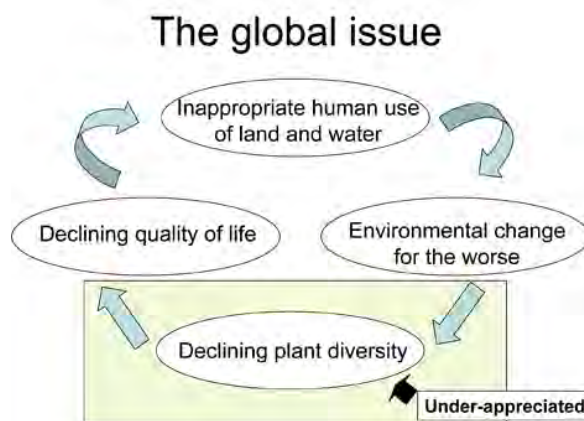
A definition of conservation that I find most useful focuses on intergenerational dialogue and benefit:

‘conservation is ... about negotiating the transition from past to future in such a way as to secure the transfer of maximum significance’ (Holland and Rawles, cited in O’Neill and Holland 2000).

The authors are landscape architects who published a paper in a book dedicated to the opening of the National Botanical Gardens in Wales in 2000. The big point of debate is what is of maximum significance. Groucho Marx had an alternative view; he said, ‘Why should I care about future generations? What did they ever do for me!’

(<http://www.grinningplanet.com/environmental-quotes/funny-environmental-quotes.htm>).

Many a true word is spoken in jest. Many people may well support Groucho rather than the landscape architects. The big question for this conference is, ‘Is plant diversity of significance and is it worth transferring to the future?’. The global issue in simple terms is this: while there are many examples of sustainable long-term human use of land and water, without question the practice of inappropriate human use of land and water is really why we are here tonight. This leads to environmental changes for the worse; it causes the decline of biodiversity including plant diversity. It forces people into a declining quality of life and the circle is complete (Fig. 1). People are placed



**Figure 1.** The global environmental issue, leading to a downward spiral towards loss of diversity and increased poverty

in desperate circumstances where ultimately they have no choice but to continue or worsen inappropriate forms of land use and water use. The under-appreciated bit in this cycle is plant diversity.

## Reservoirs of diversity

In 2000 Norman Myers and colleagues, in a paper in *Nature*, asked the question ‘Where on the planet are plant and bird species that are most threatened and most endemic (that is, confined to a region and found nowhere else, and therefore under threat) concentrated’ (Myers *et al.* 2000). They identified 25 areas, but some that you might think should feature in this list didn’t get mentioned—the major tropical areas, of South America including the Amazon basin, tropical Africa and Papua New Guinea and the like, simply because population density is lower in these areas (Cincotta *et al.* 2000). The degree of endemism of the plants and birds is lower and the degree of threat therefore was judged to be less than, for example, the Brazilian Cerrado, adjacent to the Amazon Basin, or parts of Australia, the southwest in particular (Hopper and Gioia 2004), and islands adjacent to Papua New Guinea.

Another global analysis identified areas where the authors judged unsustainable pastoralism and agriculture are most pronounced in crisis ecoregions (Hoekstra *et al.* 2005). Areas in Australia were recognised: the main wheat-growing regions in Victoria, New South Wales, South Australia and Western Australia.

## Climate and carbon

Global warming is beyond reasonable doubt. It's ironic that while the US Congress recently voted down any move for climate change legislation, its own government scientists reported on the parlous state of the global climate (Arndt *et al.* 2010). This scientific report identified ten attributes, seven of which you would predict would go up if the planet was warming and three to go down. All ten, as modelled, conformed to the predictions in 2009.

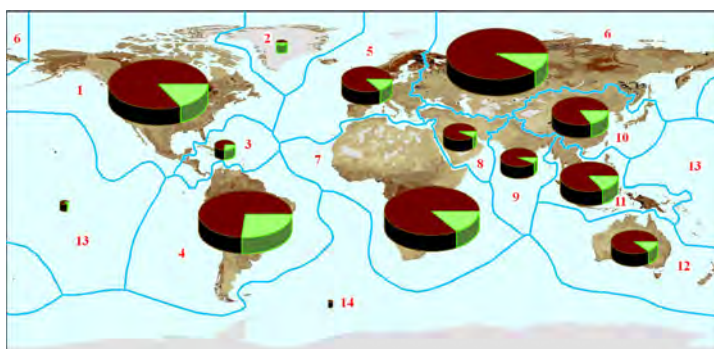
At Kew Gardens I see evidence of plant responses to global warming every day and there's a rather interesting attribute that perhaps isn't so well known, revealed by a NASA global temperature graph (<http://data.giss.nasa.gov/gistemp/graphs/>) that shows separately the global temperature trends for land in the Northern and Southern Hemispheres. Warming is not as pronounced in the Southern as in the Northern Hemisphere; this difference may be influencing peoples' attitudes towards global warming. When I arrived in the UK four years ago, the major political parties were doing everything to out-green each other, arguing that they would take the best possible action against global warming. I note, however, that this issue was scarcely mentioned in the recent election of 2010. Similarly, in the recent Australian federal election, the same applied, and the little media attention there was gave as much coverage to human-induced climate change denial as it did to mainstream scientific evidence on this vital subject.

The really big question is, what's going to happen in the next decade? Recent evidence relating to climate change (e.g. van Vuuren and Riahi 2008; Velicogna 2009; Kennedy and Parker 2010; Nicholls and Cazenave 2010; Overpeck and Udall 2010; Raupach *et al.* 2010; <http://www.aip.org/history/climate/xmillenia.htm>) indicates that we are tracking above the line for the worst-case scenario on projected global warming put forward by the IPCC (2007). We are at higher temperatures and other indicators of global change than predicted in the worst-case scenario (Rahmstorf *et al.* 2007; Füssel 2009; Smith *et al.* 2009; Trenberth and Fasullo 2010)—a situation that the ANU's Professor Will Steffen encapsulated in a recent lecture in Sydney as 'faster change and more serious risks' (cf. Steffen *et al.* 2009). That to me is a real alarm bell, and it provokes my sugges-

tion to you that the next decade is going to be critical. If we don't take action reasonably soon any responses in the succeeding decade will be much harder and much more costly (Stern 2006). Lord Stern concluded that if we delay two or three decades our attempts to slow down global warming, to get carbon emissions back to present day levels or lower, and to pay for damage caused by accelerating global change, will be economically challenging indeed.

Where is the carbon on the planet? Global terrestrial carbon stocks in protected lands, in national parks, nature reserves, state forests, etc. are compared with those in other forms of land ownership in Figure 2. Most of the carbon stocks are not protected in a way in which you would feel confident that we are looking after what remains of wild plant diversity, wild forest, nor after those that are planted for production purposes as well.

Counterbalances include emergence of carbon trading markets and an unprecedented recognition of the importance of plant diversity, most recently reinforced at the Convention on Biological Diversity's 10th Conference of Parties in Nagoya, Japan (Nayar 2010). Plants have a vital role in producing the oxygen that we breathe. We seek shelter and we maintain our health with the help of plants. Plants help us to get the water and food we need, and to manipulate our habitat in all sorts of ways. We have a tremendous focus on gardening and on other social and cultural activities that involve plants. Plants are obviously helping us mitigate global change, if in no other way but by accumulating carbon and removing it from the atmosphere.



**Figure 2.** There is no protection for 85% of carbon on land. Carbon stock in terrestrial regions: total (*proportional pie-charts*), and stored within the protected areas network (*pale green segments*). Source: Campbell *et al.* 2008.

## Sustaining irreplaceable resources

We are ambivalent to world plant diversity. We create and destroy; we socialise and annihilate; we love and hate; we celebrate and mourn. We behave in contrary ways to each other and towards the environment. We have some redeeming features; we also have many features that we would be less than proud of if we reflected on it for too long.

The big question for Australia is, how sustainable is our present way of life? There is some evidence of good sustainable practice in the nation, but also of major damage to the environment and society because of some mainstream approaches to use of land and water (e.g. Beeton *et al.* 2006; Gibbs 2009). A fundamental question that politicians in particular have to grapple with is, what are the critical environmental thresholds above which we shouldn't transgress? I am reminded of Goyder's Line in South Australia (Meinig 1961; Sheldrick 2005) as an example of good political decision-making that ultimately said, 'farming had gone too far': so far into arid land that it couldn't lead to sustainable agriculture, and human misery would be the primary outcome if farming pushed beyond the Line.

Many biologists—perhaps most—believe an extinction crisis fuelled by land-use conflict is looming. Recent scientifically-evidenced estimates of the fraction of plants and vertebrates under threat globally are at 20% and rising (Brummitt *et al.* 2010; Hoffmann *et al.* 2010). Deforestation, agriculture and urban expansion, mainly in tropical landscapes, underpin the heart of this decline in biodiversity. It is heartening and humbling to know that 80% of the plant food we consume globally is provided by just 12 species of plants—the cereals barley, maize, millet, rice, rye, sorghum, sugar cane and wheat, and tubers cassava, potato, sweet potato and yam (Grivetti and Ogle 2000). Yet we know that there are at least 7000 edible and partly domesticated plants (Williams and Haq 2002) and an estimated 30 000–75 000 edible wild species of plants on the planet (Myers 1997; McNeely and Schutyser

2003). Traditional western farming has expanded agriculture by moving into land occupied by biodiversity, bulldozing the wild vegetation and burning it to grow the main-stream crops. Some of the plant, animal and microbial diversity we were bulldozing and continue to bulldoze and burn may be part of our salvation in a rapidly changing world.

Perhaps it would be useful to highlight examples of the wild edible plants that I know well, from south-western Australia. The Noongar Aboriginals there have four staples producing carbohydrates (Fig. 3):

- Youlk, *Platysace deflexa*, which has a large, sweet, potato-like tuber, and is being trialled now for agricultural crop production. It is in the same family as the carrots (Woodall *et al.* 2009)



Youlk (*Platysace deflexa*)—a future crop?



Warrine (*Dioscorea hastifolia*)



Yanjit (*Typha*)



Mean (*Haemodorum spicatum*)

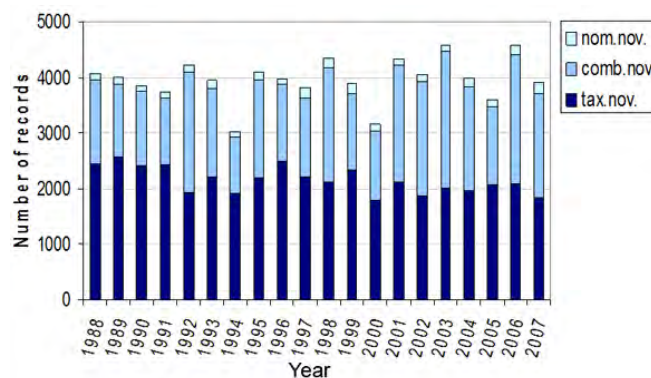
**Figure 3.** Noongar Aboriginal carbohydrate staples from south-western Australia. Photos: youlk—G.S. Woodall; warrine and yanjit—S.D. Hopper; mean—K.W. Dixon

versity? Perhaps for birds, for mammals a little less so, as we get more sophisticated in our application of DNA. In the case of plants we still don't know how many plant species there are on the planet; we are naming about 2000 new species of plants each year and another 2000 are reclassified, largely due to DNA sequence analysis (Fig. 5). An example from 1994 was the Australian wollemi pine *Wollemia nobilis*. An extraordinary case, the pineosaur as it is now called was discovered alive in a small gully just north-west of Sydney, but known from similar fossils of Cretaceous age more than 70 million years old. It has been able to easily grow this year through the worst winter that London has had for some time, with four snows (Fig. 6). It's just one example of the tolerance of plants to climatic change. We should not assume that the present distributional range reflects the future distributional range of organisms at all; there is evolutionary history and individual tolerance and plasticity to climatic extremes to take account of.

DNA sequencing is exciting the biological world and introducing new rigour into our understanding of biodiversity. Through collaboration between Kew, Missouri Botanical Gardens, New York Botanical Garden and some other leading gardens, by the end of this year we will have the first global check list of plant species since Linnaeus published his list of an estimated 5000 species of plants in 1753, but new species are being described all the time. They range from the smallest of little annuals to rainforest trees 40 metres high and examples like the wollemi pine.

## Food and environmental security

Why does this all matter? Food security is the obvious example of why it is important; coffee provides a case study. An expert working at Kew on coffee, Dr Aaron Davies, heads up a team of international collaborators who are still finding new species directly related to commercial coffee. At least 25 million farming families worldwide are dependent on coffee production. A dozen or more new species of coffee were described in 2008, including one discovered in Madagascar (*Coffea ambongensis*) with a 'bean' several times heavier than the arabica bean (Davis and Rakotonasolo 2008). Despite their importance as crop wild relatives, 70% of coffee species are in danger of extinction due to habitat loss and climate change.



**Figure 5.** Ongoing taxonomic synthesis—over 2000 new vascular plant species are described per annum globally ('tax nov' above) and another 2000 reclassified. Data from Index Kewensis and International Plant Name Index, Royal Botanic Gardens Kew: [www.ipni.org/stats.html](http://www.ipni.org/stats.html).



**Figure 6.** The wollemi pine (*Wollemia nobilis*) discovered in a sheltered deep canyon in warm temperate rainforest north-west of Sydney in 1994. This plant is growing at the Royal Botanic Gardens, Kew, London, in light snow in 2009, demonstrating the plasticity of some plants in the face of climate change, and the need for caution in inferring future distributions based on present occurrence. Photo: S.D. Hopper

The mongongo nut (*Schinziophyton rautanenii*) that occurs in semi-arid sub-Saharan Africa is another example. It's quite a beautiful nut to eat—highly nutritious; a dietary staple these days still of the San bushmen in the Kalahari, and with little need for irrigation or fertiliser. Unfortunately people have destroyed the wild habitat of the mongongo nut in Mozambique and planted orchards of cashew, mango and citrus that need both irrigation and fertiliser and largely serve a volatile export market. Many such farms (machambas) have been abandoned, but some hopeful work is underway on restoring farms in miombo wood-

- Yanjit, *Typha* bullrushes, consumed right across Australia by Aboriginal people
- Warrine, *Dioscorea hastifolia*, an edible native yam
- Mean (pronounced mee-an), *Haemodorum spicatum*, the bush onion in the kangaroo paw family. It's full of oxalic acid and rather hot to the taste, but was a major staple for the Meananger or Mineng people centred around Albany (Woodall *et al.* 2009).

We often lose sight of the fact that hundreds of millions of people rely on wild or under-utilised plants such as these as supplements to a diet made up largely of the 12 mainstream crops. If we continue to move into increasingly marginal agricultural land and reduce the populations of these wild or under-utilised crops, we reduce significantly many peoples' risk management options, when the mainstream crop fails, and starvation is the result. We surely have to find a balance now, deciding how much land is left for biodiversity, how much land is restored and repaired for biodiversity, and focus our attention on the land that is very productive and sustainably farmed with mainstream crops to feed the population of the future and of today.

A fifth of global carbon emissions are still caused by deforestation and burning—more than are caused by the world's transport system (Fig. 4). Globally we are still hooked on the notion of expanding into new lands, more and more marginal, through bulldozing and burning. When will the clearing of wild vegetation stop? When will we devise ways of getting the best out of the agriculturally productive land and getting the best out of the marginal lands that are rich in biodiversity? A paradigm shift is required.

#### Accelerating scientific research and problem-solving

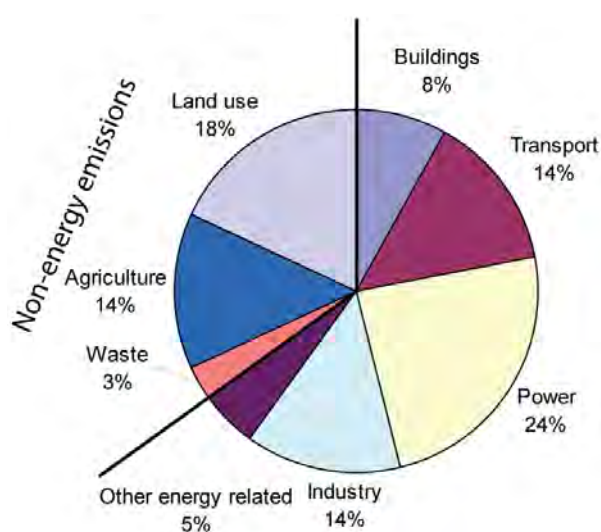
We also have an extraordinary learning curve. Upscaling the science of climate change and biodiversity is absolutely essential. Apart from understanding implications of ongoing clearing, biodiversity inventory is significantly incomplete. Even less is known about the influence of climate on biodiversity, and our biodiversity predictive tools are embryonic. The fossil record does indicate very clearly that turnover of biodiversity has happened in the past—so why don't we just let it continue to happen now? The fundamental fact is that the rate of turnover, of extinction, has accelerated by orders of magnitude with human impact

on the environment, and we have some responsibility to deal with the consequences for biodiversity because of the acceleration. Those consequences are already evident.

At Kew Gardens, I see examples of the consequences every day. London is going through some of its coldest winters and its driest summers in decades; select plants in Kew are stressed out, some have died. Geographical range changes are documented for butterflies and moths in the UK (Conrad *et al.* 2006; Menendez *et al.* 2006), and for many birds (e.g. Araújo and Rahbek 2006). Dates of flowering season are changing (Robbirt *et al.* 2010): we have a record going back 60 years of the date of first flowering of a hundred of the plants in Kew Gardens; on average they've moved forward two weeks over that 60-year period (Pain 2000; Hepper 2003). There are new invasives. Oak processionary moth—*Thaumetopoea processionea*—is now a potential cause of human health problems (Gottschling and Meyer 2006) and significant devastation to oaks in west London. It is a Mediterranean moth whose caterpillars have hairs that in the worst cases cause anaphylactic shock in people. And there are new diseases as well.

An extinction cascade is forecast—so where is biodiversity richest? Not only in the tropics; a real surprise has been the floristically rich regions of mediterranean climate around the world including that in Australia (Hopper and Gioia 2004).

Do we know what's out there in terms of biodi-



**Figure 4.** A fifth of carbon emissions is due to ongoing deforestation ('land use', lilac); total emissions in 2000 were 42 Gt CO<sub>2</sub>e (Stern 2006). Crown Copyright 2006.



land for poverty alleviation using a better informed mix of crops (Palmer and Silber 2009). So, in relation to mongongo, this is an example of a tree traditionally used to supplement commercial crops in bad seasons and whose habitat is slowly being eroded. Now people are interested in growing the tree, but it has been difficult to germinate until scientists at the Millennium Seed Bank at Kew focused on the question—we can now achieve 80% germination routinely.

Mangroves provide another example of the need to have a good understanding of biodiversity—one of the few cases published in the scientific literature of a significant failure of international aid and poor communication between biologists and people implementing a biodiversity restoration program. In a 20-year project in the Philippines, 44 000 hectares of mangrove habitat was planted up with 440 million propagules of mangrove at a cost US\$17.6 million—but up to 90% of the seedlings died (Samson and Rollon 2008). This failure was simply because the people who were planting hadn't been trained to identify different species of mangroves: they were putting mangroves that usually grow in seagrass beds into mud flats and vice versa. As we move towards more integration of mainstream and minor crops, the necessity for good taxonomy, good field identification aids and good technical knowledge will accelerate enormously.

Another example: in the wheat belt and gold fields of Western Australia, people had observed for a hundred years that the salmon gum (*Eucalyptus salmonophloia*), the biggest tree, seemed to grow on the most fertile productive land but also on the edge of salt lakes. Over the past century, more and more salt has been coming to the surface of soils in that region, and it is estimated that 30% of the productive land will become useless unless we can rectify the rising ground water (Caccetta *et al.* 2010). Salmon gums were planted in salinising land—but they just died. A colleague and I discovered in the 1980s, however, that there are two species of salmon gum, with quite different juvenile leaves: one is tolerant of salt and now called the salt salmon gum (*Eucalyptus salicola*), and the other is the normal salmon gum (*E. salmonophloia*—Brooker 1988). This is another example where rehabilitation efforts have been hindered until enhanced by good systematics (van der Moezel *et al.* 1991). Water management is an issue that's going to be globally even more sig-

nificant in the future; we can't afford failed projects.

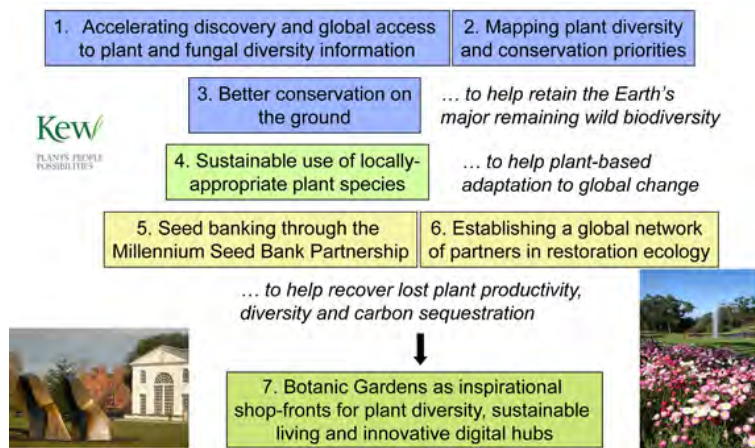
Why does biodiversity matter? I'm a biologist; I just love the bush and getting out and observing plants, animals and landscapes, and working with people in the countryside. I never under-estimate emotional attachment to the landscape and biodiversity as a motivator for people. If they really enjoy the pleasures of what the bush offers, they'll do extraordinary things, economically irrational things. I've emphasised the importance of plants, and the urgency of according them more attention. There is also a fundamental values issue that is the human condition 'writ large'. Gandhi said the 'Earth provides enough to satisfy every man's need, but not every man's greed.' That is a fundamental dilemma that we all face. Each and every one of us in our daily lives will need to adjust our expectations and some environmentally unsustainable behaviours into the future. Most importantly of all we must give hope, in particular, to young people.

## Plans at Kew

I want to describe what we've been thinking about at Kew; how we might change our business. Lord Stern made the proposition in 2006 that no walk of life, no line of business could be business-as-usual if we are to deal with the global problems we face. That's a significant challenge. We took it seriously in relation to the botanic gardens community, and have developed a forward ten-year programme at Kew based around seven strategies (Fig. 7).

The first three are about retaining the earth's major remaining wild biodiversity:

- We are focused on accelerating the rate of scientific discovery, description and communication about the identification of plants and fungi. This has to happen if we are to take the urgency seriously.
- We can apply the wonders of geographical information systems, of new computer technologies, to map plant diversity and help work out where the priority areas on the planet are most in need of attention.
- And we can work with partners who are of a mind to achieve better conservation on the ground by setting up new protected areas, and through integrated farming approaches that inject biodiversity into farming.



**Figure 7.** How botanic gardens might make a step change in scientific plant-based solutions to global environmental challenges: Kew's Breathing Planet Programme with global partners. Photos of RBG Kew, London, and Kings Park and Botanic Garden, Perth: S.D. Hopper

Then:

- We have to make greater informed use of 'locally appropriate' plant species. We are in a world of globalisation where the tendency has been to focus on the major crop species and a limited range of diversity for food production. In some places it's the best thing you can do, in other places it's the worst possible thing you could do. A sense of place is absolutely important, there is no 'one size fits all'. Agricultural scientists worked that out a long time ago. You have to tailor human endeavour, food production and living to local circumstances and use local biodiversity where and when appropriate; plants can assist adaptation to global change if we use them sustainably and intelligently.
- Seed banking is a fundamental strategy; the Millennium Seed Bank, an initiative of Kew in the year 2000, now has 54 countries as partners with 100 organisations. It achieved its objective in October last year of securing, in the country of origin and backed up by an extra collection in the Millennium Seed Bank south of London, 10% of the world's wild plant species, on time and below budget. Sir David Attenborough has described this as an ambitious and successful global conservation program. Seed banking is a fundamental, critical insurance policy.
- If we are going to put biodiversity back into some landscapes, or to grow new crops as

climate changes, we have to have the germplasm well stored in international standard facilities and dispersed to the people who really need it and who have the right technical information. Australia has a challenge with agricultural germplasm, but Australia has been one of the major participants in the Millennium Seed Bank. Every state and territory now has a seed bank for wild plant species with well-trained staff and perhaps there's scope for collaboration between the agricultural and biodiversity sectors.

- Establishing a global network of partners in restoration ecology to facilitate the use of seed banks and other botanic garden resources in the urgent repair and re-establishment of damaged native vegetation.
- And finally a challenge for botanic gardens is to use their unique opportunity as mainly urban visitor attractions to convey some of the positive things each of us can do to help deliver a more sustainable future. Botanic gardens throughout the world, under the auspices of the Global Strategy for Plant Conservation (UNEP 2002), are applying a similar approach, tailored to local circumstances (e.g. Council of Heads of Australian Botanic Gardens 2008).

I want to leave with you messages of hope. Sustainable cities can be designed and maintained. Clean skies are something we enjoy. A hundred years ago any photo of London skies would have been fundamentally different to those today, and the same applies to many cities. Botanic gardens around the world are gardens of hope. If they have the right policy and the right public support they can achieve an enormous amount, as has happened already with the Millennium Seed Bank Partnership, and we are motivated to play our part in that regard. Seed banking, seeds of hope, are fundamental; there is an exciting nexus looming between mainstream agricultural crop seed banks and biodiversity seed banks because of the emerging priority of wild relatives of crops.

South Korea last year pledged \$38.1 billion towards a major green program generating a million jobs including river cleaning, dealing with water shortages and reforestation. The Guiana govern-

ment has formed a partnership with the Norwegian government to protect rainforests under a deal that will reward the Guianan government according to the carbon credits it accumulates. Guiana had gone out to the market-place and asked if anybody in the world wanted to support it in moving people who are destroying rainforests—because it's the only livelihood they have had—and offer sustainable livelihoods outside the rainforests.

I recommend Ian Lowe's book, *A Big Fix—Radical Solutions for Australia's Environmental Crisis*, as it includes a discourse on what makes a sustainable society. The requirements are not new, and have been achieved in varying combinations somewhere around the world in the past. We should rethink agriculture and biodiversity. High-quality agricultural land is largely sequestered. Our big challenge is to get the best possible out of that land to feed the world. Conventional cropping is a major contributor to both climate change and biodiversity loss—a new model has to come. What should we do? Adapting conventional crops is absolutely fundamental. Broadening the plant biodiversity used for crops, using inter-cropping and under-utilised crops, is going to be much more significant in the future, as is giving back to nature and restoring biodiverse carbon sinks on marginal lands. Seed banking I've emphasised. We have to focus on research. Many of the challenges in the future are unprecedented; the notion that we know enough and just need to get on and do it is bereft and short term. We have to conserve local knowledge in particular if we are to conserve biodiversity.

## Conclusion

We are at a great historical moment comparable to that when slavery was abolished. Comments in the UK parliamentary records at that time mirror those made today by climate change skeptics ... the end of the economic regime as we now know it; the end of the way we operate. And yet people took the moral decision not to proceed with slavery, and the world survived and prospered in a new way.

We are in a similar situation now in that the way we are living has detrimental effects on the environment and causes irreplaceable loss of biodiversity. We have to move into a triple-bottom-line accounting system where natural capital and social capital are valued as much as financial capital.

Plant biodiversity does underpin human existence and livelihoods, and yet we continue to destroy wild plant diversity at an alarming rate, with one in five plant species recently estimated to be under threat of extinction. We are at a turning point for plant biodiversity of unprecedented importance to people in a rapidly changing world. We do have a steep learning curve. We mustn't forget investment in science. Targeted plant diversity science in botanic gardens and elsewhere offers solutions to global problems and an important message of hope—not all, but some solutions. We can feed the world through sustainable use of biodiversity. But will we?

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