Diversity, simplicity, and the optimisation of agrobiodiversity

Dave Wood and Jill Lenné

Slide 1

We have approached this from two contrasting standpoints. Wood from the standpoint of a tropical ecologist, who then began collecting crop seed in traditional agroecosystems; Lenné as a tropical pasture pathologist with extensive field work in both natural and managed pasture systems. We developed the working hypothesis that there are 'appropriate' levels of biodiversity in both natural and agroecosystems, mainly dependent on abiotic factors such as climate (drought and flood), fire, and salinity. This presentation is an attempt to discover just what these 'appropriate' levels are in natural and agro-ecosystems, so that agrobiodiversity can be 'optimized' – rather than 'maximized' – to confer sustainability on farming old and new.

This presentation is divided into three parts:

- First, a look at the concept of 'agrobiodiversity' (slides 1-6):
- Then, using a knowledge of agrobiodiversity, to investigate the validity of simple natural models for ecological field management (and the place of fields in agro-landscapes) (slides 7-21);
- Finally, we argue that the conflicting views of farmers and bio-conservationists over biodiversity can be resolved through an approach to farming based on the ecology of natural models (slides 22-28).

What is ‘agrobiodiversity’?

`All crops and livestock and their wild relatives, and all interacting species of pollinators, symbionts, pests, parasites, predators, and competitors’

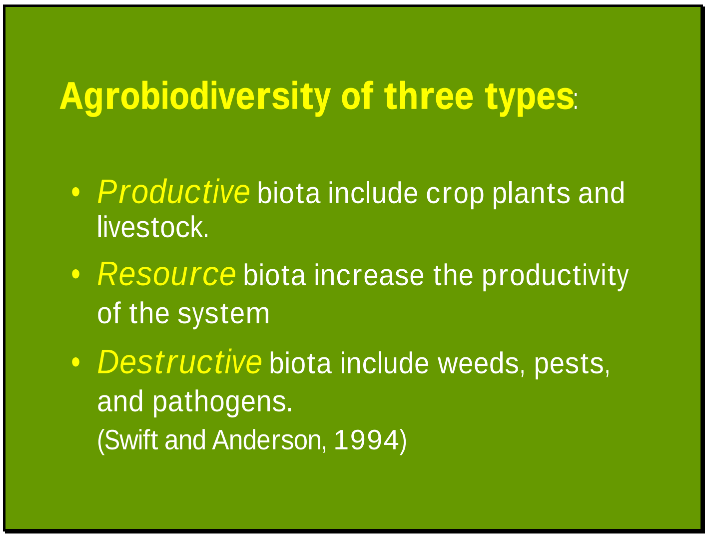
(Qualset *et al*., 1995)

Slide 2

The first record we can find in print of the word ‘agrobiodiversity’ was Wood (1992). The word had been used in letters and minor reports a year previously (and may have been first used, in the form agri-biodiversity, in Indian literature – not yet traced).

At first, the word was used as a synonym for plant genetic resources, but the Qualset *et al*. (1995) definition – bringing out the ecological and biological richness of agroecosystems - should now replace this early usage.

In terms of this meeting, ‘agrobiodiversity’ is a biological bridge. On one side of the bridge is the genetic level, represented by the various adaptations based on genetic differences between varieties of crops and breeds of domestic animals. On the other side of the bridge is the broader concept of ‘agrodiversity’, the farm in the socio-economic and geographical landscape. ‘Agrobiodiversity’ is the bridge that connects these two – determining the complex biological interactions in agroecosystems that can make or break farming.



Slide 3

The division used by Swift and Anderson (1994) emphasizes this distinction between the genetic component (crop plants and livestock,) and the wider agrobiodiversity of resource and destructive biota.

The relationship between these three classes is a key issue for the sustainability of farming. To what extent does the productivity of crops and domestic animals depend on the bonus provided by the resource biota, in contrast to the damage caused by the destructive biota?

Another way of posing this question is to ask: Do we have knowledge to economically promote the resource biota; and to prevent damage caused by destructive biota?

By far the greatest contribution that a concept of 'agrobiodiversity' can contribute to sustainable farming is to provide answers to the above question. Both traditional and formal knowledge can contribute (Wood and Lenné, 1999). But there is a continuing need to reassess traditional farming in the light of changing paradigms of formal research. In our own experience, when this is done, traditional farming regularly proves itself to be conceptually superior to some of the transient paradigms of modern science (Wood, 1998). A case in point is 'agroecology'. Rather than being closely based on research in traditional agroecosystems, large parts of this discipline interprets traditional agriculture through the lens of simplistic or even dogmatic ideas from the ecology of yesteryear, overlain with environmental politics. The danger for farming is that, as ideas change in ecology, agroecology has proved to be quite resistant to change. We will demonstrate specific instances of this later.

Agriculture = `the tilling of fields’

- Management of agrobiodiversity is all-important
- But agroecosystem management regimes will depend on the required outputs of farming
- Socio-economic factors may predominate over ecological factors

Slide 4

A determining feature of agriculture is increasing the competitiveness of crops related to weeds. Indeed, a defining feature of agriculture (literally) is the ***tilling of fields***.

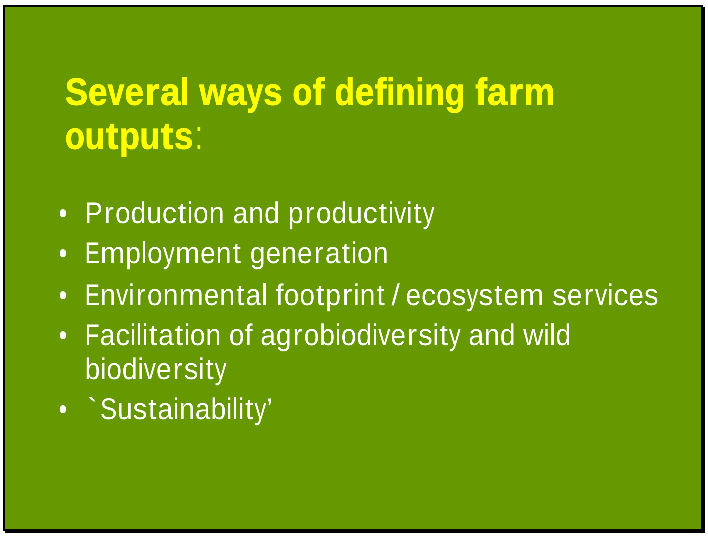
Agriculture can be seen as a pipeline, with a series of *filters* and *pumps*. The filters take out unwanted biodiversity, and the pumps add and encourage wanted biodiversity – most notably of crops and domestic animals. In both traditional and modern agriculture, the management of these filters and pumps is highly knowledge specific.

The tilling of fields is the first filter – removing weeds. It is also a pump: producing soil conditions that favour useful organisms.

The first and main ‘pump’ applied to fields is seed or planting material, whereby crops gain a competitive advantage over weeds. Transplanted rice is an effective way of reducing weed competition.

There is a strong socio-economic determinant to all farming, and this may mask the ecological determinants of farming. The first economic determinant is: Is it worthwhile adding inputs to get better (higher or more secure) outputs? This determines the possibility of e.g. irrigation; protected production such as glasshouses; and nutrient addition.

The second main socio-economic determinant is food security. Extreme forms of ‘landesque’ agriculture include terracing and hill gardens may be a response to threats to community security in the lowlands. The hill gardens characteristic of C. America and Java were not ‘ecological’ agriculture, but a response to dispossession of lower and flatter land for use for colonial plantations of export crops (Hayami, 2001). The widespread phenomenon of ‘home garden’ is not principally determined by ecology, but by proximity to the home to prevent theft, and to give a continual supply of non-staple foods.



Slide 5

Depending on labour and input constraints, crop yield may be subordinate to a range of other criteria: for example, perennial gardens may need to produce a range of food over long time spans.

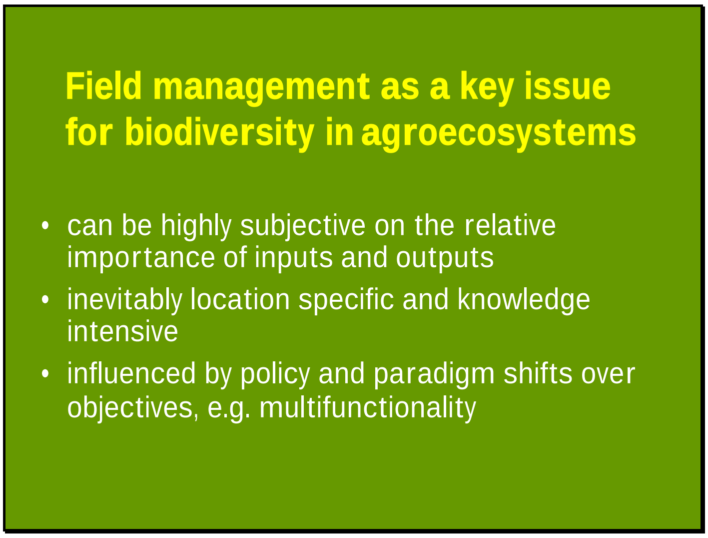
In countries where there are substantial crop surpluses, or with a political need to subsidize farming, or where farming causes substantial environmental damage, there may be a range of other objectives for farming. For example, the idea of ‘multifunctional agriculture’, which has objectives wider than food production (this becomes increasingly attractive to rural populations in Europe and farm subsidies are withdrawn).

These objectives may be environmental: lessening pesticide use and fertilizer run-off; providing a biodiversity-friendly farm to encourage resident and transient wildlife; providing ecosystem services such as rainfall retention, carbon sequestration, erosion control. Other objectives may be aesthetic or recreational or social: maintaining farm populations; farms as ‘lungs of the cities’; and as a base for rural sports such as hunting.

This has been described by Zadoks (1999), for the Netherlands, as ‘integrated’ agriculture: ‘cleaner production, less polluted environment, the restoration of biodiversity, better nature conservation, pleasant landscaping and recreation of townpeople.’

However, as direct subsidies to food production are reduced (as with the reform of the Common Agricultural Policy in Europe) there is substantial lobbying to maintain indirect subsidies to farming. ‘Biodiversity’ and its supposed contribution to ‘sustainability’ has become an issue of increasing political importance (and the subject of much lobbying).

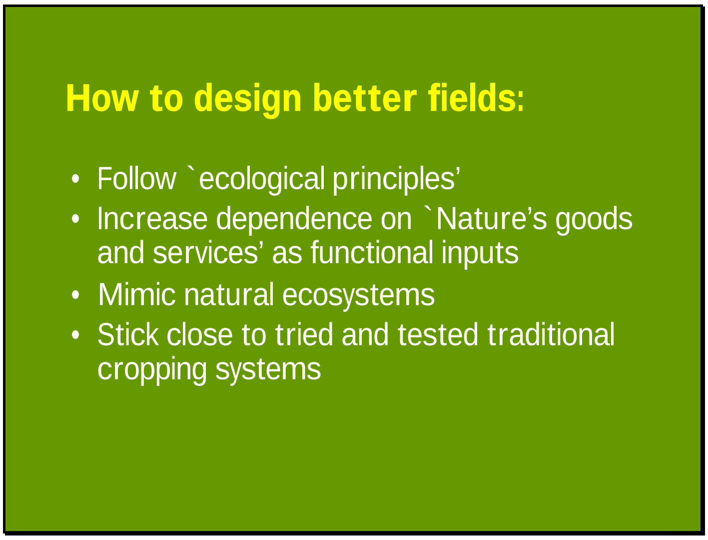
But it may not be relevant – politically or biologically – for developing countries to subsidize post-industrial-revolution perceptions of the countryside. And problems of definition remain - for example, what is `sustainability' and how is it measured?



Slide 6

In the face of all these variables, is there a generic approach to biodiversity-friendly field management?

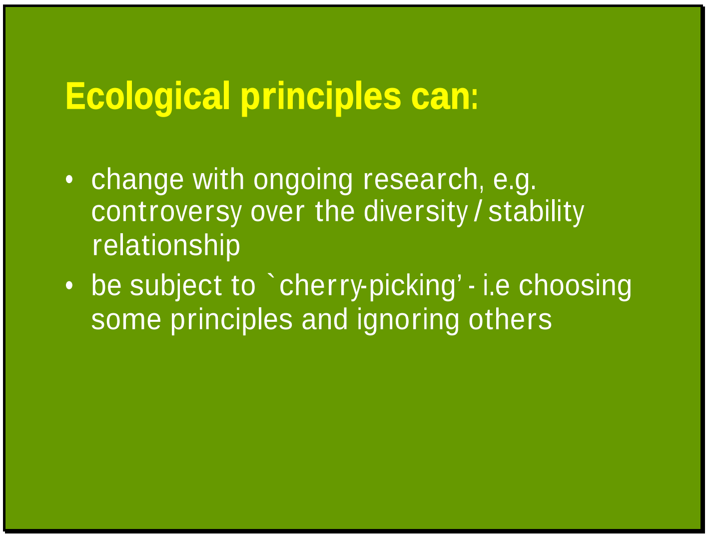
Critically, can and should ideas of multi-functionality from rich countries, with high-external input agriculture and crop surpluses, be applied to agroecosystems in developing countries? Note that yet more biodiversity becomes both the objective and the indicator of success in approaches to multifunctional agriculture. Is this appropriate for developing countries?



Slide 7

We have been bringing together the complexities of farming and agrobiodiversity – ecological, social, economic and political, all compounded by major geographical and environmental differences between regions of agricultural production

In the face of this massive complexity how can we understand enough to design 'better' fields? Four ways are suggested here, in turn each will be considered.

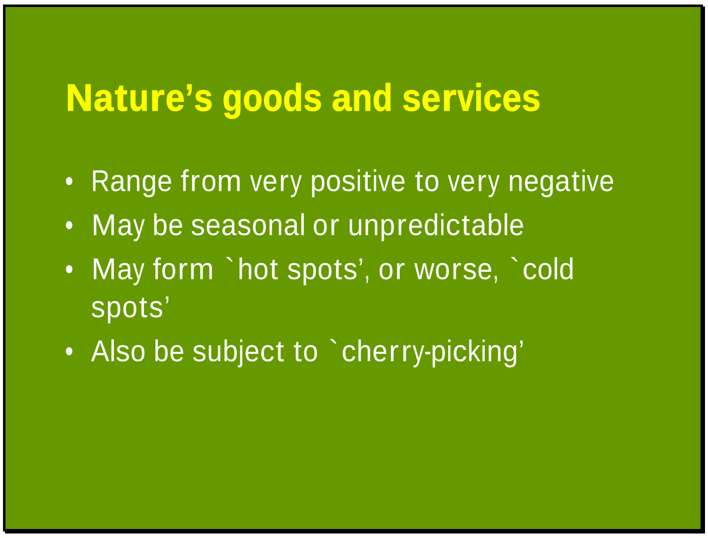


Slide 8

An appeal to ecological principles is a dangerous approach. The principles of last year may become the dogmas of next year.

Ecology is at present in a state of flux and dispute. For example, a revision or reversal of concepts, a 'turbulence in ecology', 'radical changes in fundamental paradigms', and a 'bit of a muddle' are all a feature of recent ecological debate (Hobbs and Morton, 1999).

There is particular confusion and dispute over the effect of plant diversity on productivity (the major effect in key experiments was the inclusion of a legume, *Trifolium*: farmers have known the benefit of cereal-legume intercrops probably for millennia) An earlier debate, relating diversity to ecosystem stability is still unresolved after more than 30 years.



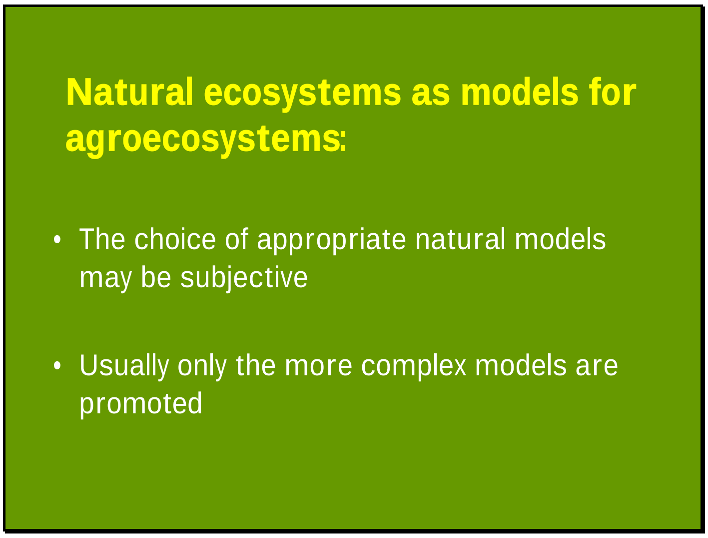
Slide 9

There are several problems with a concept of 'Nature's goods and services':

- The abiotic aspect of 'Nature' may be considerably more important than the biotic. For example, most cereal production is from strongly seasonal climates (either with a strong dry/cold season; or with seasonal flooding).
- 'Goods and services' are not all positive: promoting the good and preventing the bad (for example, weeds) is a skill of farmers rather than 'Nature'.
- In addition to 'goods and services' *from* Nature, agroecosystems may contribute multiple services *to* Nature (for example, as a haven for wild biodiversity; in erosion control).

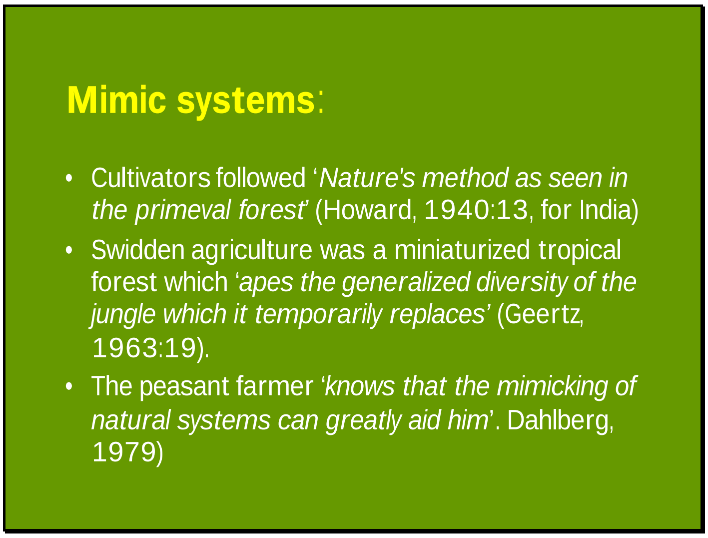
But very often there may be trade-offs between wildlife and farming. For example, elephants can roam 20km from wildlife sanctuaries in India and prefer feeding on secondary vegetation around villages and crops (Danesh *et al*. 2001). There is a sound biological reason for this preference: secondary vegetation is less protected by anti-feedants (tannins and the like) and more nutritious to elephants than forest species.

Crops near forest may need special protective features. For example, rice awns protect against seed-eating birds. 'The nearer the crop to the forest, the greater the protection needed...' (Burkill, 1925). This is more useful in Malaya - where rice areas are smaller and closer to forest, than in 'wide rice plains, like those in Bengal'. In general, as noted by Burkill, 'where there is forest on either hand, a strip of rice suffers greatly from the depredations of forest animals and birds: such loss diminishes with the greater remoteness of the forest.'



Slide 10

We want to spend some time on this, as we have just completed a review that has unexpected conclusions (Wood and Lenné, 2001).

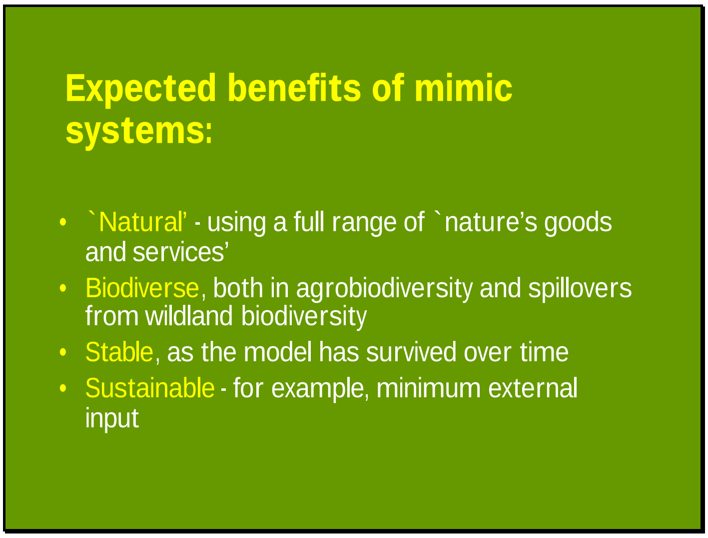


Slide 11

There are copious exhortations to use Nature as a model for fields.

Further examples:

- Mimicking nature would allow the strong ecological foundation on which agriculture originally developed to be found again, by making use of natural ecosystem processes and interactions (Gliessman, 1998)
- The patterns and processes discernible in natural ecosystems still remain the most appropriate standard available to sustainable agriculture (Jackson and Piper, 1991)
- Native ecosystems are time-proven survivors, and it is logical to learn from them and imitate their useful traits. (Ewel, 1999).

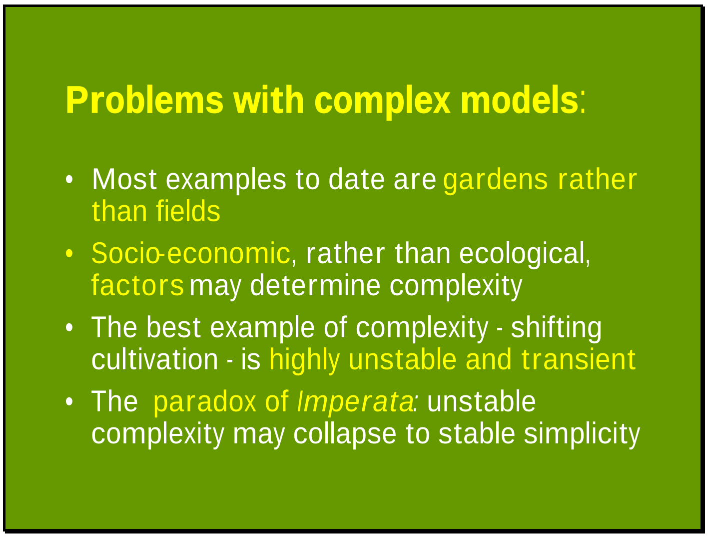


Slide 12

There are two contrasting appeals of a 'natural' approach to field management:

- There is the popular perception that 'natural' is somehow good;
- There is the scientific fact that our present 'natural' ecosystems are the survivors of an evolutionary process of adaptation and winnowing, and are thus more likely to be ecologically robust.

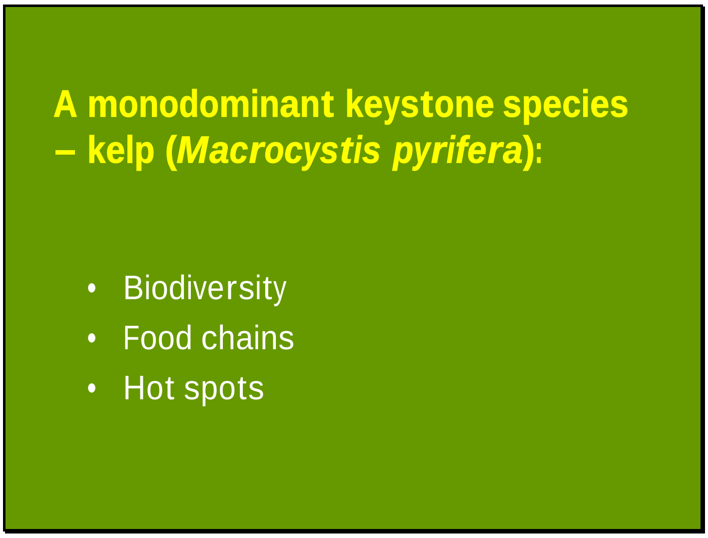
We concentrate of this latter feature of naturalness.



Slide 13

A major problem to modelling fields on natural ecosystems is the choice of appropriate models. Of the wide range of options, only structurally complex models have hitherto been chosen. But in agriculture, complex systems either collapse – as with shifting cultivation, or demand a great deal of management skills and inputs – as with home gardens.

Does Nature provide examples of simpler and more stable ecosystems that could serve as models for fields?



Slide 14

More than 150 years ago Darwin (1845) described the monodominant beds of kelp in the Southern Ocean:

`The number of living creatures of all Orders, whose existence intimately depends on the kelp, is wonderful…On shaking the great entangled roots, a pile of small fish, shells, cuttle-fish, crabs of all orders, sea-eggs, star-fish, beautiful Holothuriae, Planariae, and crawling nereidous animals of a multitude of forms, all fall out together '

'Amidst the leaves of this plant numerous species of fish live, which nowhere else could find food or shelter; with their destruction the many cormorants and other fishing birds, the otters, seals, and porpoises, would soon perish also...'.

*`Yet if in any country a forest was destroyed, I do not believe that nearly so many species of animals would perish as would here, from the destruction of the kelp.' (*Darwin: `The Voyage of the Beagle')

So we know that natural monocultures can be very biodiverse (*Rhizophora* mangrove vegetation is another example of monodominance with exceptional biodiversity). Can we find simple natural ecosystems more relevant as models for agriculture?

Slide 15

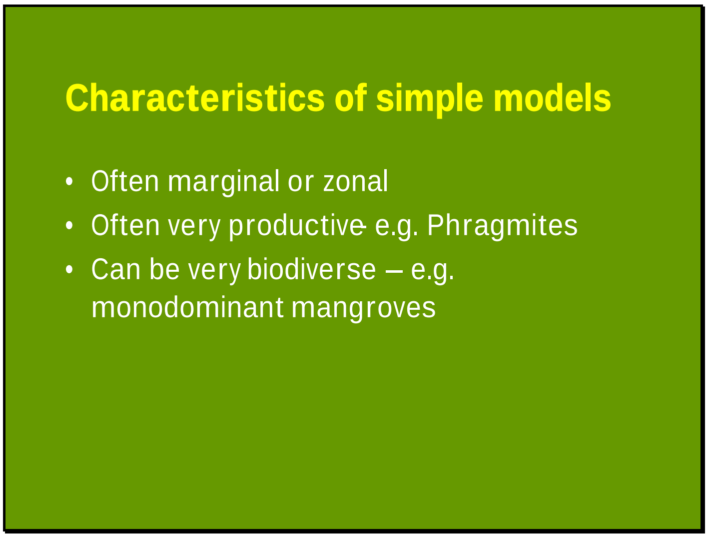
One clue on where to look is the fact that most of our food comes from annual cereals – that is grasses. Grasses are phenomenally successful plants:

> *'grasses benefit from a fire regime that is lethal to many other plants, and, having co-evolved with herbivores, can sustain a level of predation sufficient to cripple many competitors'* (Clayton and Renvoize, 1986).

But grasses are wind pollinated. As tree cover increases, grasses retreat to more open spaces to ensure pollination. Are there open grasslands with wild relatives of crops?

The answer to our search for stable grassland systems seems to be 'yes': for example, the fire-climax *Imperata* grassland that replaces shifting cultivation is ecologically tough and persistent. The slide shows a monodominant perennial grassland after an annual burn in south India.

But, significantly, wild relatives of our important cereals – rice, wheat and sorghum – are found as monodominants in grassland ecosystems. We have provided extensive evidence for this in Wood and Lenné (2001).



Slide 16

But to be of use as models for agriculture, we need to know a great deal about the ecology of monodominant grass systems.

A recent workshop on ‘Agriculture as a Mimic of Natural Systems’ asked how can we relate the structure and function of a mimic system ‘when so little is known about the underlying processes that confer persistence and resilience on the natural system on which the mimic is based?’ (Lefroy *et al*. 1999). This workshop was considering complex systems, where the more complex the system, the more there will be dispute over the relationship of structure to function, and the lower likelihood of uncovering appropriate techniques for field management.

However, the problem remains for simpler grass systems: systems ancestral to agriculture have yet to be investigated ecologically. In order to judge the relevance of natural models for cereal cropping, we need to know two types of information:

- What are the *determinants* of these ecosystems? For example, they appear to be found with strong dry seasons; geographically marginal habitats; and seasonal disturbance such as fire or flood. But the necessary field work has yet to be done.
- What are the *characteristics* of these systems. For example, how stable are they? What are the population genetics of the dominant species? How much associated biodiversity can these systems maintain (and what can we learn of the function of this associated biodiversity)? Why are wild relatives annual?

These important questions remain unanswered. Ecologists prefer to work on more complex forest and grassland systems.

However, a major fault in current ecological research is the interminable debate about *characteristics* of ecosystems (for example, the diversity-productivity debate noted above) rather than the highly important identification of the environmental *determinants* of monodominance. We suggest that early farmers knew enough of the determinants of natural monodominant grassland to mimic this in field management. Thereby farming could maintain the ecological and evolutionary robustness of natural vegetation.

Advantages of simple fields:

- ecologically tough keystone species
- ecological and evolutionary continuum from nature, therefore stable
- easily managed – including appropriate mechanization

Slide 17

In the past, the results of ecological research on structurally simple systems (for example, mangrove and *Spartina* systems) have not been applied to the management of fields. However, there are indications that in such systems a single species can outcompete all others and become dominant – perhaps as a result of unique adaptations to stress. Then as a monodominant and 'keystone' species, it can provide the biomass and shelter for a wide range of dependent biodiversity (as Darwin had found with kelp so long ago).

This speculation on a 'single keystone species but with great associated biodiversity' seems to be supported by irrigated rice Schoenly *et al*. (1998) reported a '*staggering taxonomic richness, interconnectedness and spatiotemporal flux*', with a '*complex and rich food web of generalist and specialist predators and parasites that live above, below, and at the water surface*'. Settle *et al*. (1996) has also suggested the importance of field detritus in contributing to biodiversity in rice fields.

Thus agroecosystems based on nature can be ecologically tough and have high associated biodiversity. In addition, with simple keystone species, they will be relatively simple to manage, as one set of conditions, rather than a complex of conditions, will determine the ecological health of the keystone species. This simplicity will be a bonus to field management.

But there is a great need for ecological research on 'ancestral ecosystems' to test the validity of what are at present speculations.

Effects of scale and the distribution of biodiversity:

- Diversity in gardens
- Structural simplicity in monoculture fields
- Optimization at the landscape level, using a range of different strategies

Slide 18

We have gone to some lengths to show that cereal monocultures can be very much ‘eco-farming’, soundly based on Nature, relatively stable, with the potential to support rich crop-associated biodiversity. But note that their very simplicity allows or encourages intensification. As in nature, the more nutrients flow, for example, into a wetland ecosystem, the more the monodominant species captures nutrients and the higher the resulting biomass. In fields, it is the ability to tolerate high levels of intensification, rather than their status as monocultures, which has brought monocultures into disrepute. A better understanding of the ecological status of natural monocultures could allow better field management. For example, there must be limits to just how much nutrient input natural monocultures can tolerate.

In the light of the existence of robust ‘natural monocultures’, it is certainly ecologically-naïve to argue for ‘breaking the monoculture’ (Altieri, 1999; Pimbert, 1999) in the belief that this is somehow justified by ‘agroecological principles’. Rather, agroecology must now significantly revise its view of the natural world to accommodate monocultures.

By accepting monocultures as an ecologically-acceptable method of producing food, we have more possibilities of managing biodiversity in the landscape.

Our thesis is that monoculture fields are based on nature, can be biodiverse if skilfully-managed, and in addition, produce most of our food. This allows a revised view of the scale of farming, its relation to biodiversity, and the place of food production in the landscape.

If fields are central to global food production, they are flanked on one side by the smallness of gardens, and on the other side by the largeness of landscapes.

Slide 19

As the terminology of ‘horti-culture’ and ‘agri-culture’ indicates, the functional division between gardens and fields has a long history.

There are multiple biodiversity benefits from gardens. Our irrigated garden in India is a haven for biodiversity sheltering and feeding during the dry season on perennial or irrigated crops. It is also crop-diverse, with 47 different crops (from large trees to annuals), often with multiple varieties. However, the main determinant of biodiversity in gardens is the variety of fresh food that we need on a regular basis, for which we are prepared to invest considerable effort, not least in irrigation and nutrient input, including recycling. A secondary determinant is that we tolerate monkeys taking mangoes and corn and fruit bats eating guava: unlike a poor farm family, we have the economic ability to replace lost crops from the market.

We argue that gardens are to a large extent *socio-economic constructs*. While they are rich in transient and crop-associated biodiversity, this biodiversity is *secondary* and even incidental to the need to produce diverse food throughout the year. In short, the biodiversity depends on the garden, and not the garden on the biodiversity. Indeed, in our most highly managed ‘gardens’´- controlled glasshouse production of high-value vegetables - biodiversity may be stripped away as a problem to production: here the economic facet is paramount.

Our failure to distinguish between socio-economic and supposedly ‘ecological’ reasons for the biological complexity of gardens constantly leads to complex traditional gardens being recommended as generic ecological models for farming.

There is also an underrated ethico-political dimension to home gardens that has a bearing on their value as biodiverse and ecologically-appropriate models for food production. In a remarkable synthesis of the politics of colonial control and the geographic setting of agriculture in South East Asia, Hayami (2001) showed that in hilly forested areas of the Philippines and Indonesia gardens are a rational response to the spread of colonial plantations on lower and better land which dispossessed peasant farmers. In contrast, in the rich delta lands of Thailand and the Mekong, small farmers farming their own land grew monoculture rice (with an annual supplement of water and nutrients from the Himalayas!). In this geographical setting, as in much of Latin America and the Caribbean, forest gardens are a response to colonial domination, the ending of slavery, and agricultural economics, rather than sound ecological models for farms, as often promoted.

Slide 20

In contrast, the main determinants of biodiversity in cereal fields are first, *abiotic* factors – usually a strong dry season, favouring a monodominant crop - and then the 'Darwin effect': the possibility of a seasonal build-up of high crop-associated biodiversity based on the high productivity of crop and crop residues. And this productivity is often raised by nutrient and water input. As with gardens, the biodiversity in fields is mainly secondary, but this time determined by climatic factors rather than socio-economic ones

The socio-economic and ecological differences between fields and gardens are usually ignored or misinterpreted. Paradoxically, we suggest that the monoculture cereal field is mainly an *ecologically-appropriate* production system (the ecology being a response to abiotic factors), whereas the garden is *a socio-economic construct*. However, the close proximity of fields and gardens allows a seasonal movement of biodiversity and the maintenance of higher levels than would be possible with either fields or gardens.

Slide 21

The landscape-level disposition of agricultural production is, of course, determined by geography – the relation of people to land.

The common perception is that the land holds biodiversity and agriculture replaces and destroys biodiversity. For two main reasons this is far too simplistic:

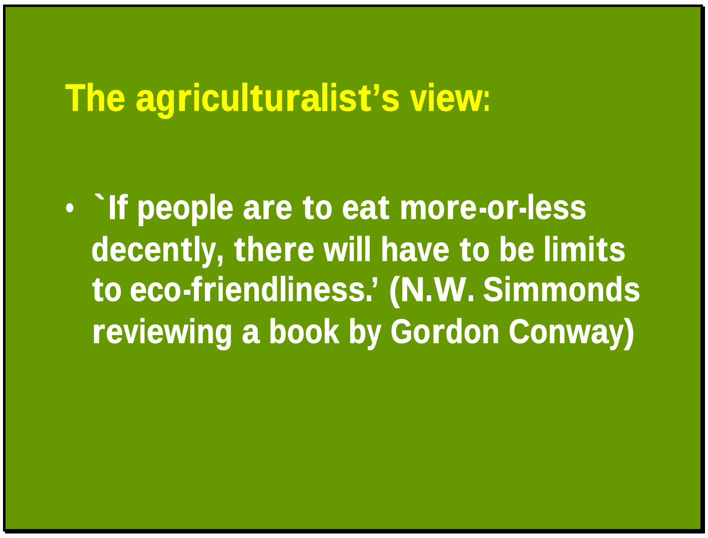
- There is no linear relation between loss of land area and loss of biodiversity. For example, a reduction of land area by 50% leads to a far less than 50% loss of biodiversity.
- Increased intensification of agriculture can take pressure off natural vegetation.

By combining these two facts, it is possible for improved agriculture to co-exist with natural biodiversity (and also add agrobiodiversity to the world's stock of biodiversity, as a valuable bonus)

However, there be conflicts at the landscape scale (Zadoks, 1999):'Whereas nature conservation and natural biological control require biotopes (refuges) with maximum connectivity to promote desirable species, pest and disease control wants to mimimize connectivity to reduce the spread of noxious species.'

Slide 22

[no text]



Slide 23

[no text]

Slide 24

These are entrenched positions – indeed, dogmas.

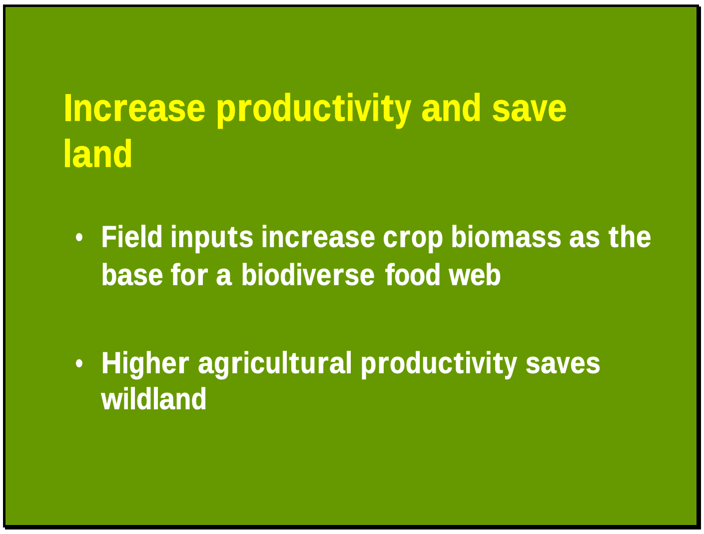
- The conservationist misreads agriculture as always unnatural and destructive of natural biodiversity; yet increased crop yields can take pressure of wildland.
- The crop scientist misreads ecology as of little relevance to agricultural production (especially ecology as presented by agroecologists and 'eco-farming'); yet a better knowledge of 'Nature's Fields' could allow sustainable intensification.

The current international approach to agrobiodiversity does nothing to overcome these dogmas and contrasts. The main international text is decision III/11 of the third meeting of the Conference of the Parties to the Convention on Biological Diversity. Paragraph 1 of III/11 gave a specific objective: '(a) To promote the positive effects and mitigate the negative impacts of agricultural systems and practices on biological diversity in agro-ecosystems and their interface with other ecosystems'. This formulation reflects the 'conservation' parentage of the CBD. The management objective is 'practices to enhance the biological diversity in agroecosystems' (and not to make agriculture more productive, or even more sustainable).

The problems inherent in this approach are compounded in the 'Elements of a Programme of Work' (UNEP/CBD/SBSTTA/5/10). Their survey of the scope of agricultural biodiversity begins with and places most emphasis on a survey of agricultural biodiversity (8.a) and then the services it provides (8.b).

However, as we have indicated above, by far the most important of agrobiodiversity in the seasonal production systems that produce most of out food are '*abiotic factors'* which the SBSSTA programme of work dismisses in two lines (8.c). Yet an understanding of the role of abiotic factors as major ecological determinants is fundamental to the better management of agricultural biodiversity. The SBSTTA report is 'putting the cart before the horse' in looking at 'ecological services' without fully considering abiotic factors.

This failure to understand the key role of abiotic factors is repeated with *'socio-economic factors'*, which receives minor emphasis (8.d). Yet it seems that a combination of abiotic factors determines major cereal systems, and socio-economic factors, the very biodiverse garden systems. Compared with these, programme elements such as pollinators are of decidedly secondary status (most of our food comes from wind-pollinated or clonal crops).



Slide 25

COP III/11 talks of the impact of … agricultural practices on biological diversity in agroecosystems and their interface with other systems. In fact the main impact of agricultural practices globally is the enormous amount of land saved from agricultural expansion by crop intensification. COP III/11 ignores the excellent record of agriculture on this key issue.

The figures for 'land-saving' through intensive agriculture deserve to be better known:

- Estimated land saved by Green Revolution cropping: 250million ha.;
- The total cropland of the US is 120million ha.;
- Total tropical protected areas (forests, woodland, and savannas) 208m ha.

Similarly, over the next 50 years it has been estimated for plantation forestry 'huge volumes of wood will be provided from relatively small areas of land …. Most of the world's natural forest will be left for other purposes.' (Nair, 2001; and others in same volume). In a remarkable parallel with cereal fields, we note that many such plantations use provenances from and also mimic the monodominance of wild forests of Eucalyptus, Caribbean pines, and teak.

This intensification of monodominant fields and forest, based on natural models, allows a co-existence and biological synergy between food and timber production and wildland biodiversity. But intensification, based on naturally monodominant models, will also help to produce more food from the same land.

Intensification can even help wildlife on-farm: for example, timely applications of fertilizer in the Netherlands encourages earthworms on which nesting birds rely for food. It is worth emphasizing here that the common perception that the Green Revolution caused a damaging increase in fertilizer application is wrong. In India Green Revolution wheats *followed* 15 years of rapid advance of productivity based on ‘a revolution of fertility on irrigated lands’ (Hutchinson, 1974): that is, the new varieties made production more fertilizer-efficient.

There is an ongoing tendency to exaggerate the local damage caused by agriculture, and ignore the landscape-scale benefits to biodiversity resulting from agricultural intensification.

Slide 26

The take-home message is that we need a substantial rethink of the biodiversity-agriculture interface.

Agriculture is our greatest and most necessary human achievement. It can only continue to meet our needs through the knowledgeable management of agrobiodiversity.

Firstly, we should recognize the ecological robustness and environmental validity of cereal monocultures – they are the best hope of continuing to feed the world and preventing the collapse of wildland diversity BUT we need to know far more about the survival strategies of monodominant wild cereals. AND we can learn from Darwin's observations on kelp – monodominant vegetation can be wonderfully biodiverse and a `hot' ecosystem for conservation (we know this can be true for rice).

Secondly, we must better distinguish between gardening and farming when making prescriptions for eco-friendliness. The reasons for biodiversity in gardens are predominantly socio-economic. While gardens worldwide are exceptionally important for food security, dietary diversity and nutrition, biodiverse gardens cannot be used as ecological models for fields.

A greater emphasis on agrobiodiversity can have two clear benefits:

- Enhanced sustainability and continued productivity of a vast range of agroecosystems (thus conserving through use, 'appropriate' levels of biodiversity);
- In turn, removing the need for agriculture to expand into wild habitats (thus effectively conserving habits crucial to wild biodiversity).

This meeting is a clear indication that we must broaden our thinking on the interface between the environment and agriculture. In our view farmers worldwide have already done an excellent job in feeding growing populations and also taking pressure off wildland and thereby saving biodiversity. A deeper understanding of the role of agrobiodiversity and of how 'Nature's Fields' function could allow farmers to enhance their past efforts both to feed growing populations and also to protect the environment.

References

Altieri, M.A. 1999 The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment 74, 19-31.

Burkill, I.H. 1935 A Dictionary of the Economic Products of the Malay Peninsula, Crown Agents, London, p. 1595

Clayton, W.D. and Renvoize, S.A. 1986 *Genera Graminum*: Grasses of the World, HMSO, London, pp 16-17.

Dahlberg, K.A. 1979 Beyond the Green Revolution, Plenum Press, New York, p 227.

Danesh, Miah M., Lutfor Rahman, M. and Farid Absan, M. 2001 Asessment of crop damage by wildlife in Chunati Wildlife Sanctuary, Bangladesh. Tigerpaper 28(4), 22-28.

Darwin, C. 1845 Journal of Researches into the Natural History and Geology of the Countries Visited During the Voyage of H.M.S. Beagle Round the World, (2nd Edn.) John Murray, London.

Ewel, J.J. 1999 Natural systems as models for the design of sustainable systems of land use, Agroforestry Systems 45, 1-21, p 2.

Geertz, C. 1963 Agricultural Involution: the Processes of Ecological Change in Indonesia, University of California Press, Berkeley, p 82.

Gliessman, S.R. 1998 Agroecology: Ecological Processes in Sustainable Agriculture, Ann Arbor Press, Chelsea, MI, 1998, p. 27.

Hayami, Y. 2001 Ecology, history, and development: a perspective from rural Southeast Asia. World Bank Research Observer 16, 169-198.

Howard,, A. 1940 An Agricultural Testament, Oxford University Press, London, 1940.

Hobbs, R.J. and Morton, S.R. 1999 Moving from descriptive to predictive ecology. Agroforestry Systems 45, 43-55.

Hutchinson, J. 1974 Crop plant evolution in the Indian subcontinent. In: J. Hutchinson, (ed.) Evolutionary Studies of World Crops. Cambridge University Press, Cambridge, pp. 151-160.

Jackson, W. and Piper, J. 1989 The necessary marriage between ecology and agriculture, Ecology 70, 1591-1593.

Lefroy, E.C., Hobbs, R.J., O'Connor, M.H.O. and Pate, S. 1999 Preface [Agriculture as a mimic of natural systems]. Agroforestry Systems 45, vii-ix.

McNeely, J.A. and Scherr, S.J. 2001 Common Ground, Common Future: how Agriculture can Feed the World and Save Wild Biodiversity. IUCN, Gland.

Nair, C.T.S. 2001 Changing forest scenarios: some history and a few speculations. Unasylva 204, 3-11.

Pimbert, M. 1999 Background Paper 1 Agricultural Biodiversity. FAO/Netherlands Conference on the Multifunctional Character of Agriculture and Land.
Qualset, C.O., McGuire, P.E. and Warburton, M.L. 1995 'Agrobiodiversity': key to agricultural productivity. California Agriculture 49(6), 45-49.
Schoenly, K., Mew, T.W. and Reichardt, W. 1998 Biological diversity of rice landscapes, in N.G. Dowling, S.M. Greenfield, and K.S. Fischer (eds) Sustainability of Rice in the Global Food System, Pacific Basin Studies Center/IRRI, Manila, pp. 285-299.
Settle, W.H., Ariawan, H., Astuti, E.T. Cahayana, W., Hakim, A.L. , Hindayana, D., Sri Lestari, A. and Pajarningsih 1996 Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77, 1975-1988.
Swift, M.J. and Anderson, J.M. 1996 Biodiversity and agroecosystem function in agricultural systems. In: Schulze, E.-D. and Mooney, H.A. (eds) Biodiversity and Ecosystem Function. Springer-Verlag, Berlin, pp. 15–41.
Wood, D. 1992 Talking Point: A Matter of Good Breeding. New Scientist. 18 Jan. 1992.
Wood, D. 1998 Ecological principles in agricultural policy: but which principles? Food Policy 23, 371-381.
Wood, D. and Lenné, J.M. (eds) 1999 Agrobiodiversity: Characterization, Utilization and Management. CABI, Wallingford, pp. 490.
Wood, D. and Lenné, J. 2001 Nature's Fields: a neglected model for increasing food production. Outlook on Agriculture 30, 165-174.
Zadoks, J.C. 1999 Reflections on space, time, and diversity. Annual Review of Phytopathology 37, 1-17.