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Agricultural Biodiversity is Essential for Adapting to Climate Change

Agricultural biodiversity and climate change are rarely discussed in the same context. However, there are close mutual links: Agrobiodiversity is reduced through climate change and – at the same time – is crucial for coping with the consequences of a changing climate. This interrelationship is particularly important since the entire diversity of genes, species and ecosystems in agriculture represents the resource base for food. With climate change progressing, genetic resources are gaining a new quality as they are vital for adaptation.

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Effects of Climate Change on Agriculture

The implications of climate change for agriculture have opened a new window in the discussion of agrobiodiversity. Today, the world-wide loss of agricultural biodiversity is mainly caused by changing agricultural practices and production systems along with the so-called industrialisation of agriculture. At present, environmental change is a minor factor reducing the diversity of crops and livestock, but is likely to gain importance. Five climate change related factors can be identified: the rise of temperature, changes in precipitation patterns, the rise of sea levels, increased incidence of extreme weather events and the increase of greenhouse gases in the atmosphere, with carbon dioxide being the most prominent.

The ***rise in temperature*** – commonly known as global warming – is probably the most obvious phenomenon of climate change. Since 1861, the global mean annual temperature has increased by 0.6 °C as atmospheric carbon dioxide concentrations have risen by 32 percent. It is unlikely that such a concentration has ever been reached during the past 20 million years (Malhi et al. 2002). Emission scenarios suggest that carbon dioxide concentrations will reach 550 parts per million within the next 40 to 100 years – corresponding to almost twice the pre-industrial concentrations. This rise will be accompanied by a further increase in temperature (IPCC 2001). Depending on the geographical region, scientific estimates propose an additional mean annual temperature rise of 1 to 5.8 °C (Caldeira et al. 2003), and increases are expected highest in tropical and subtropical regions. Generally, the speed of temperature rise will decide whether agroecosystems will be able to adapt. It seems likely that the temperature rise will be too fast for natural adaptation and will reduce species diversity; at best, organisms may survive through migration. In the affected regions, this will lower agricultural yields. A gloomy scenario is presented by Parmesan (cited in WWF 2003): A temperature rise of 2 °C may result in a loss of some species, but with possible management options at hand; with a rise of 4 °C many species will be lost, with few coping options remaining. Finally, a rise of 6 °C will leave no more potential to adapt to climate change. As an example, Simonett (1989) investigated the impact of temperature on coffee production in Uganda. He predicts that an increase of 2 °C will dramatically reduce the area suitable for Robusta coffee; only higher altitude areas are expected to remain.

Indirect temperature effects may not be less important. With rising temperatures, the evaporation from soils increases, decomposition of organic matter is accelerated, the incidence of pests and diseases is aggravated (Pimentel 1993).

Changes in water supply pose another problem of increasing importance. In the last century, subtropical regions received most likely around three percent less precipitation and more frequent droughts. In contrast, the northern hemisphere likely experienced five to ten percent higher rainfall in the same period. At the same time, increasing seasonal and regional rainfall irregularity has been observed; research suggests that this trend will become more pronounced (IPCC 2001). An indication of this is the increasing use of drought tolerant varieties at many tropical sites. Similar trends can be observed in animal husbandry. For instance, camels are increasingly replacing cattle and goats in extremely drought prone areas of Ethiopia (Oxfam 2002).

Among the various ***greenhouse gases*** not only carbon dioxide is of concern. Chlorofluorocarbons, for instance, have severely reduced the atmosphere's protective ozone layer. And, as a general rule, every one percent reduction in ozone concentration causes a two percent increase in ultraviolet radiation reaching the earth. Research from Hawaii suggests that ozone depletion by 25 percent might reduce soybean yield by 19 to 25 percent (Teramura et al. 1990). High levels of UV radiation may also nurture pests and diseases. For example, fungus infection rates in wheat increased by 9 to 20 percent when experimental UV radiation was increased by 8 to 16 percent above normal (Biggs and Webb 1986).

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In summary, dramatic implications are expected for agriculture and food supply. But the global trend displays enormous regional differences. Ironically, the poorest are most at risk. Fischer et al. (2002) predict that by the year 2080 the 40 poorest countries, located predominantly in tropical Africa and Latin America, may lose 10 to 20 percent of their basic grain growing capacity due to drought. It is also argued that many rain fed crops in the tropical belt of Africa and Latin America are approaching their maximum temperature tolerance; their yield may fall sharply with a further temperature rise (Richards 2003). In contrast, yield increases are expected in temperate regions due to higher temperatures, increased carbon dioxide levels and partly higher rainfall; a country like China might experience a rise in production by about 25 percent (Fischer et al. 2002).

As a consequence, a two-pronged strategy is required: mitigation and adaptation. On the one hand, all possible efforts have to be made to reduce greenhouse gas emissions and mitigate climate change, in agriculture for instance by methods of organic farming (Kotschi and Müller-Sämann 2004). On the other, fast and appropriate action is needed to enhance ecosystem capacity to adapt to changes already inherent in the systems but not yet fully visible. Both, mitigation and adaptation, have to be part of anticipatory prevention strategies.

Agrobiodiversity – How Much Shall be Conserved?

The continuous loss of agricultural genetic resources – a process in which climate change is gaining importance – is a matter of growing concern (IPCC 2002). In search of adequate responses, one has to consider that genetic resources are crucial to coping with climate change (Umweltbundesamt 2004). Plants and animals with no economic value so far may become important, and new breeds able to tolerate environmental stress will be needed. But how much agrobiodiversity shall be conserved to secure our future? Can we base public conservation strategies on mathematical modelling, which sets priorities for conservation and with which the optimal degree of conservation is calculated, as proposed for instance by Weitzman (1993, 1998)? Or must we conserve all we have because the future needs for human survival are unknown?

Valuing genetic resources with mathematical models is not yet relevant to decision-making. On the other hand it seems unrealistic to conserve all resources irrespective of any valuation. As a basic principle, a maximum of genetic resources should be conserved at the lowest possible public cost. Hence, a concept is required that goes far beyond *ex-situ* conservation, which, at present, is the predominant approach for conserving plant genetic resources. Storing seeds in refrigerated banks or botanical gardens is essential. But this method exceeds the capacity of public funding, is of limited scope and security (FAO 1997, GRAIN 1996). Therefore, gene banks can only be complementary to a more comprehensive conservation approach (Hammer 2004).

Such an approach relies primarily on *in-situ* concepts, i.e. farmers and farming communities who are conserving and breeding seeds on their farms and in their villages (figures 1 and 2, p. 100/101). Farmers have done so for thousands of years, have been ignored or neglected by the formal seed sector during the past 40 years and are slowly being rehabilitated. On-farm conservation is not necessarily less costly – but the costs are mainly borne by farmers, whereas the benefits are private and public.

Latest concepts of *in-situ* conservation follow the idea that conservation and the use of genetic resources are closely linked. True to the slogan "use it or lose it", plant species or animal breeds should be used whenever possible, should contribute to securing rural livelihoods and to rural culture. "As long as farmers themselves find it in their own best interest to grow genetically diverse crops, both farmers and society as a whole will benefit at no extra cost to anyone" (Bragdon 2004).

As a consequence, economic or social benefits have to be identified for seemingly useless crops or farming systems, and value has to be discovered in them. For example: Wild plants may be used for medicinal purposes; wheat landraces grown under organic agriculture may obtain a higher price; farming communities as a whole may profit from agrotourism if they maintain biological diversity, etc. However, it will not be possible to find a market for everything that should be protected. Therefore, a remainder will have to be protected, although (currently) not used – a service that has to be paid for by the public.

Species Adaptation – But How?

Another argument that calls for a revised understanding of agrobiodiversity conservation is the necessary adaptation to climate change: The ecosystem's capacity to be resilient and adaptive to environmental change relies fundamentally on genetic diversity. Adaptation describes a plant's, animal's or ecosystem's capacity to adjust to changes such as heat, drought, or salinity – an adjustment enabling them to overcome constraints, take advantage of new opportunities and cope with the consequences of changing environments.

Adaptation is a process. What matters is not so much the drought resistant minor millet landrace, well stored in isolation and deep-frozen in a gene bank. Rather, species must be exposed to the environment, considering the wide agroecological variation of sites. Resistance of plants to environmental stress (e.g. drought tolerance) is mostly a multi-genetic characteristic best developed by *in-situ* exposure to it. In contrast, it is difficult to achieve such traits through genetic engineering.

The social dimension is no less important. Adaptive capacity building has to address the poor and should enhance their human and social capital. The focus on women accounts for the fact that in most rural societies women have traditionally been the seed keepers, the preservers of genetic resources.

A strategy as outlined above addresses regional and local agroecological variations; it offers site-specific solutions. The corpo- >

rate sector, on the other hand, follows the law of economy of scales and aims to distribute a standardised variety or a whole cropping system technology as widely as possible.

Urgent Action is Required

The various international development initiatives are hardly aware of the close relationship between climate change and food security and the role agrobiodiversity has to play. This concerns without distinction the programmes to fulfil the Millennium Development Goals (MDGs), the *National Adaptation Programmes of Action (NAPAs)* by the *United Nations Framework Convention on Climate Change (UNFCC)* (UNEP 2005) and others. Adaptation to climate change in agriculture, if considered at all, is discussed mainly with respect to improved water management (in view of more frequent droughts and floods). Agrobiodiversity – although a fundamental resource for adaptation – is mostly forgotten.

Therefore, it must become imperative to sustainably manage agricultural diversity and to use it systematically in order to cope with the expected environmental challenges. The following aspects deserve consideration:

- Stronger coordination is needed between main global programmes such as the *United Nations Framework Convention on Climate Change*, the *Convention of Biodiversity* and the *International Treaty on Plant Genetic Resources for Food and Agriculture* (CBD 2003, UNEP 2005).
- Agrobiodiversity conservation is to be made a basic component of adaptation strategies to climate change.
- Programmes that manage agricultural genetic resources need to reconsider their strategies. Formal institutional systems based on gene banks (*ex-situ* conservation) must be broadened with respect to an integrated management system that includes farmer based *(in-situ)* conservation (Almekinders 2003).
- *In-situ* conservation of agricultural biodiversity must be made an integral part of agricultural development and supplemented by *ex-situ* conservation.

Only the public sector can take the lead in implementing such a comprehensive approach, in which the private sector has an important supportive role. National and intergovernmental laws and regulations will have to provide the necessary legal frame. Civil society organisations (CSOs) as well as the private sector are becoming increasingly important in filling this frame with development reality on the ground. So far, CSOs have taken the pioneering task of developing and spreading suitable concepts at grassroots level. For instance:

FIGURE 1: A comprehensive approach to conserve agrobiodiversity includes *in-situ* concepts: A Chinese farmer from Hunan Province ...

- They have catalysed world-wide a boom of farmer initiatives that practice Organic Agriculture (Kotschi 2005) based on maintaining biodiversity, avoiding the use of hybrid seeds and prohibiting transgenic crops.
- They are increasingly supporting local seed conservation initiatives, such as Navdanya in India, that aims to "empower local communities (...) to protect and conserve their biodiversity and defend their community rights to seeds and knowledge" (Navdanya 2000).
- They have founded an alternative market for plant breeding and seed production. Mainly in Europe, various initiatives have emerged that maintain, improve and make available open-pollinating varieties of cereals and vegetables (Almekinders and Jongerden 2002), many of which are the result of cross-breeding and selection over centuries and in danger of getting lost. Kultursaat e. V., an association in Germany that releases new varieties as public property, is a prominent example.[1]

All such activities make it very clear: Genetic resources must remain largely in the public domain; with well-balanced benefit-sharing concepts among the stakeholders that use and conserve agro-genetic resources. Generally, the *in-situ* approach offers a great chance to shape a future worth living.

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1 *www.kultursaat.com/start.html*

FIGURE 2: ... prefers a local maize variety with high genetic diversity and better taste to the common, uniform hybrid varieties.

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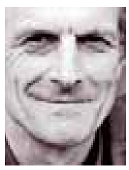

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