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Climate change, energy and food

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CLIMATE CHANGE AND BIODIVERSITY FOR FOOD AND AGRICULTURE

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Introduction

On February 2008, FAO and Bioversity International held an international workshop on Climate Change and Biodiversity for Food and Agriculture, in partnership with the Platform for Agrobiodiversity Research (PAR) and the Secretariat of the Convention on Biological Diversity. The aim of the workshop was to contribute to the on-going debates of the international community on climate change, food security and biodiversity.

Biodiversity for food and agriculture includes the variability among living organisms contributing to food and agriculture, including also the forestry and fisheries sectors. This concept includes diversity within species, between species and of ecosystems. While biodiversity for food and agriculture will be significantly affected by climate change, it will also be an important element in the development of production strategies to meet the challenges of climate change.

Unfortunately, biodiversity for food and agriculture and climate change have rarely been discussed together. Previous global assessments on climate change dealt with the possible impacts of climate change on biodiversity, ecosystem services and food and agriculture separately. So far, there has been little systematic attempt to explore the threats posed by climate change to the biodiversity most important to food security, and on the crucial role biodiversity for food and agriculture will have in responses to climate change. The organizers of this workshop, therefore, decided to focus the agenda and discussions of the workshop on two key themes where biodiversity interfaces with climate change: the ecosystems services provided by agricultural biodiversity and genetic resources for food and agriculture.

This document will inform FAO's High Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy, to be held 3-5 June 2008. It briefly summarizes key findings and identifies some suggestions for responding to climate change through the conservation and sustainable use of biodiversity for food and agriculture.

This synthesis could also inform, where relevant, discussions on future work of FAO, particularly the Commission on Genetic Resources for Food and Agriculture and the International Treaty on Plant Genetic Resources for Food and Agriculture. The document will also inform the work of Bioversity International and of the Platform for Agrobiodiversity Research which seeks to identify gaps and research needs in relation to climate change and biodiversity. Relevant information may also feed into other processes, such the Convention on Biological Diversity.

Climate change and biodiversity for food and agriculture: key findings

Ecosystem services provided by agricultural biodiversity

Agricultural biodiversity provides a number of benefits within production systems. These include benefits associated with production and productivity, agro-ecosystem function, and human well-being, as summarized in Table 1. Thus agricultural biodiversity contributes directly to production and productivity, ecosystem function and human well-being.

Table 1: Biodiversity benefits to agriculture through ecosystem services

Provisioning	Regulating	Supporting	Cultural
<ul style="list-style-type: none"> • Food and nutrients • Fuel • Animal feed • Medicines • Fibres and cloth • Materials for industry • Genetic material for improved varieties and yields • Pest resistance 	<ul style="list-style-type: none"> • Pest regulation • Erosion control • Climate regulation • Natural hazard regulation (droughts, floods and fire) • Pollination 	<ul style="list-style-type: none"> • Soil formation • Soil protection • Nutrient cycling • Water cycling 	<ul style="list-style-type: none"> • Sacred groves as food and water sources • Agricultural lifestyle varieties • Genetic material reservoirs • Pollinator sanctuaries

Adapted from UNEP, 2007. *Global Environment Outlook. GEO 4: environment for development*. United Nations Environment Programme. Malta, p. 172.

The 2005 Millennium Ecosystem Assessment estimated that by the end of this century, climate change will be the main driver of biodiversity loss¹ Along with predicting a higher risk of extinctions, the Intergovernmental Panel on Climate Change (IPCC) reports that temperature increases will impact ecosystem functioning, including those important for food supply. The latest IPCC Report concludes, with high confidence:

For increases in global average temperature exceeding 1.5-2.5°C and in concomitant atmospheric carbon dioxide concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions, and species' geographical ranges, with predominantly negative consequences for biodiversity, and ecosystem goods and services e.g., water and food supply²

The IPCC also reports that, by 2100, the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances such as flooding, drought, wildfire, insects, ocean acidification, and other global change drivers such as land-use change, pollution, over-exploitation of resources)³. Smallholder and subsistence farmers, pastoralists and fisherfolk are likely to suffer complex, localized impacts of climate change⁴.

It is therefore very likely that climate change will affect the ecosystem services provided by agricultural biodiversity. This impact will be different for the different components of agricultural biodiversity. There will be mismatches in response times to climate change between interacting species (plant and pest). Certain genotypes will be favoured against others and communities within agro-ecosystems will reshuffle. This means potentially that there will be trophic decoupling of food webs and disruption of mutualism and evolutionary processes, leading to loss of functional biodiversity and to localized impacts in the delivery of ecosystem services such as lack of pollination,

¹ Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute, Washington, DC

² ⁴ IPCC, 2007: *Summary for Policymakers*. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, page 11.

³ . *ibid*

⁴ Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber and F.N. Tubiello, 2007: *Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge (UK), page 275.

loss of soil biodiversity and capacity for nutrient cycling, or loss of natural biological control leading to potential new pest outbreaks.

Agricultural biodiversity has never been properly integrated in agricultural adaptation strategies to climate change, which creates a challenge for the future. Enhancing ecosystem services through use of agricultural biodiversity will be crucial, given that it contributes to adaptation, mitigation and resilience.

- *Adaptation:* good management of agricultural biodiversity allows production systems to adapt to changing conditions while maintaining productivity. Enabling the sustainable use of agricultural biodiversity has a huge potential for developing win-win strategies with multiple benefits such as coping with climate change, conserving biodiversity and improving human well-being.
- *Mitigation:* Agricultural soils are important carbon sinks with great potential to mitigate climate change and soil biodiversity plays an important role in soil carbon cycles. Better understanding and management of soils have potential to bring important conservation and use benefits, mitigate climate change, avoid land degradation, and improve water retention and productivity. Biologically based agricultural systems that require less external energy input could also contribute to mitigating climate change.
- *Resilience:* extreme climate events will increase disturbance of agro-ecosystems, which can be buffered through the sustainable use of agricultural biodiversity.

Genetic resources for food and agriculture

The IPCC asserts that roughly 20 to 30 percent, varying from 1 percent to 80 percent among regional biotas of species assessed so far (in an unbiased sample), are likely to be at increasingly high risk of extinction as global mean temperature exceed 2 to 3° C above pre-industrial levels.⁵ Loss of biodiversity will affect food and agriculture, and may well lead to significant losses of genetic diversity within the species most important for food and agriculture.

Genetic resources are the living material that local communities, breeders and researchers use to adapt to changing socio-economic needs and ecological challenges. Maintaining and using a wide basket of genetic diversity at a time of climate change will be an essential insurance policy for the food and agriculture sectors.

With climate change, the value of genetic resources for food and agriculture will increase in the near future. Many of these resources will become more threatened, as global climate change will erode genetic diversity and destabilize food ecosystems significantly. A brief analysis of trends in loss of genetic diversity at a time of climate change is given in Appendix 1.

The sustainable use of genetic resources for food and agriculture will be the foundation for many of the adaptation strategies required in food and agriculture. In order to adapt to climate change, plants and animals important for food security will need to adjust to abiotic changes such as heat, drought, floods and salinity. As climate change brings new pest and diseases, new resistances will be required for animal breeds, fish breeds and crop and forest varieties. Genetic diversity which is currently underutilized may become more attractive to farmers as a result of climate change. A summary of the usefulness of genetic diversity in food and agriculture in adapting to climate change impacts in production systems is given in Table 2.

⁵ Fischlin, A., G.F. Midgley, J.T. Price, R. Leemans, B. Gopal, C. Turley, M.D.A. Rounsevell, O.P. Dube, J. Tarazona, A.A. Velichko, 2007: *Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, page 213.

Table 2: Using Genetic Diversity to adapt to Climate Change

Adaptation to	Genetic Diversity Usefulness				Examples of traits and management practices
	Plant	Animal	Forestry	Aquatic	
	Genetic Resources				
New abiotic stress	X	X	X	X	<ul style="list-style-type: none"> • Adaptation of crop varieties to allow new timing of sowing or harvesting. • Improvement of crops to increase water use efficiency, tolerance to heat stress or use of nutrients. • Establishment of forest breeding populations with different relationships between latitude and temperature climate. • Selection of animal breeds with effective thermoregulatory control. • Use of fish species and strains adapted to low quality waters. • Use of underutilized species, breeds or varieties adapted to harsh environments. • Community-based management of a wide portfolio of plant genetic diversity to allow adaptive capacity.
New biotic stress	X	X	X	X	<ul style="list-style-type: none"> • Use of disease-resistant cultivars, multilines or farmers' composite mixtures to strengthen crop resilience and resistance. • Enhancement of the resistance or tolerance to disease by management of animal genetic resources. • Use of diversification strategies to increase the number of species and genetic diversity being farmed to reduce vulnerability.
Extreme climate events	X		X		<ul style="list-style-type: none"> • Breeding of boreal forest species to control timing of spring growth to avoid late frosts. • Use of genetic diversity of fire-tolerant forest species. • Community conservation of particular local varieties adapted to cope with extreme climatic events.

Most examples described have been taken from two sources:

FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*. Rome (Italy).

FAO. 1998. *The State of the World's Plant Genetic Resources for Food and Agriculture*. Rome (Italy).

The suitability and distributions of species and genotypes in food production systems will change greatly as well as the distribution in ecosystems of many wild relatives of species relevant to food and agriculture. Many rain-fed crops in tropical areas may approach their maximum temperature tolerance if temperature increases. An increase in temperature may also reduce the area suitable for some crop species in certain regions, while it may expand the areas in other regions. The suitability of current crop genotypes to local conditions will therefore change in both positive and negative ways, depending on the crop and region, but it will affect many production systems. Similar trends can be observed in animal husbandry, with some species substitution already occurring in some drought prone areas in Africa (camels substituting goats, sheep or cattle). Countries will increasingly depend on food species and genetic diversity from other countries and regions to adapt their food and agriculture. Interdependence among countries will increase as a result of climate change, as indicated in Table 3.

Table 3: Country interdependence on genetic resources for food and agriculture with climate change

	Selected examples
Plant genetic resources	Loss of potato crop wild relatives in South America will reduce the genetic portfolio available for future breeding worldwide.
Animal genetic resources	Many breeds cannot be genetically improved fast enough to adapt to climate change. Consequently, livestock keepers will need to be able to access to a wide portfolio of genetic resources. Movement of breeds with desired traits will occur, increasing the flow of genetics, in particular South-South exchange.
Forest genetic resources	In temperate forests, local extinctions of certain forest species in its southern distribution range will negatively impact the adaptation strategies of the species in its central distribution range, as genetic diversity from the South may be needed to enable the adaptation capacity to new climatologic conditions.
Aquatic genetic resources	Loss of genetic diversity of <i>Tilapia</i> species in Africa may significantly decrease the breeding options of these species worldwide, but particularly in Asia, where it is an important protein resource for the poor.

Biodiversity for food and agriculture: key suggestions to respond to climate change

Developing the knowledge basis to monitor biodiversity trends and associated risks

Assessment

Analyzing whether climate change may constitute a threat for biodiversity in the future requires understanding the extent and distribution of biodiversity for food and agriculture, and its vulnerability and adaptation patterns. Matching this information with that available from climate change models will be a basic requirement to inform conservation and adaptation strategies. Lack of characterization and evaluation of genetic resources for food and agriculture will be an obstacle in developing adaptation mechanisms to climate change. Evaluation is currently an important bottleneck across all types of genetic resources. Improving information systems for genetic resources and the dissemination of relevant information to users will be an important priority for the future.

Suggestions for future action

- Improve biodiversity national inventories to include relevant spatial information assessing threats caused by climate change to species, populations or genotypes of relevance to food and agriculture.
- Improve knowledge on the genetic processes, such as geneflow, introgression, local populations and extinctions that allow or undermine species adaptation to climate change of relevant biodiversity for food and agriculture.

- Undertake predictive modelling of future distribution of genetic resources for food and agriculture under different climate change scenarios to inform national strategies.
- Develop biodiversity monitoring plans to analyze changes in delivery of ecosystem services due to climate change in specific farming systems, to inform place-based adaptation strategies.
- Strengthen characterization and evaluation of genetic resources for food and agriculture as a fundamental basis to enable sustainable use.
- Develop or strengthen information systems on genetic resources, including early warning systems.

Mainstreaming: inter-sectorial cooperation and integrated planning

Assessment

Biodiversity for food and agriculture and climate change have rarely been discussed in the same context. Previous global assessments on climate change have dealt with its possible impacts on food security and on biodiversity, but, so far, there has been no comprehensive analysis at the global level of the threats posed by climate change to the biodiversity most important to food security and on the crucial role biodiversity for food and agriculture can play to respond to climate change. On the other hand, previous global assessments of the status and trends of biodiversity for food and agriculture had limited focus on climate change.

Given its potential to contribute to coping with climate change, the sustainable management of biodiversity for food and agriculture should be made a basic component of adaptation strategies.

Suggestions for future action

- Improve cooperation between the United Nations Framework Convention on Climate Change and relevant biodiversity forums, such as the Commission on Genetic Resources for Food and Agriculture, the International Treaty on Plant Genetic Resources for Food and Agriculture and the Convention on Biological Diversity.
- Integrate climate change dimensions into future global assessments on biodiversity for food and agriculture, so that the findings can inform future climate change assessments by incorporating agricultural biodiversity perspectives.
- Develop integrated strategies to tackle climate change adaptation and mitigation, food security and rural development, and the sustainable management of biodiversity. In doing so, identify opportunities to deliver these triple dividends, but also the trade-offs and conflicts and ways to resolve them.

Building adaptive capacity through biodiversity management in farming systems

Assessment

Improving our understanding of the ecosystem services provided by agricultural biodiversity and of how these may be affected by climate change will be a key element in the development of place-based sustainable agricultural responses to climate change. Responses will need to be dynamic given the complex changes occurring at different scales, as explained above.

Smallholder and subsistence farmers or pastoralists are likely to suffer complex, localized impacts of climate change. These vulnerable communities are among those most dependent on biodiversity and on the provision of ecosystem services to guarantee their livelihoods and well-being. Farmers and local and indigenous communities adapt to change continuously, and agricultural biodiversity, especially crop and livestock diversity, has traditionally formed an important element of farmer risk management strategies. Strengthening farmer adaptation strategies, their ecological knowledge and local institutions will enable development of more effective adaptation strategies to climate change. It

will also allow farmers and rural communities to play a role in climate change discussions and policy. Developing local response strategies will depend on the complementary knowledge of farmers and researchers.

Suggestions for future action

- Identify which agro-ecosystems, components or properties of agricultural biodiversity are most or least sensitive to climatic variability.
- Downscale climate change data to allow informed decisions on biodiversity planning by farmers and rural communities.
- Put in place long-term monitoring of functional agricultural biodiversity in production systems and identify key biodiversity indicators to facilitate such monitoring.
- Promote local institutions to manage agricultural biodiversity and strengthen community capacity to access genetic resources and associated information to cope with climate change.
- Strengthen the dissemination of knowledge, appropriate technologies and tools to improve management practices related to agricultural biodiversity and ecosystem services.

Developing climate-change informed plans and policies for genetic resources for food and agriculture

Assessment

Very few national and international programmes on genetic resources for food and agriculture factor climate change into their conservation and sustainable use strategies. Lack of information is currently an obstacle, but available data suggest that there are serious challenges to confront, as climate change is likely to cause a significant and irreversible loss of the genetic diversity that is critical for the sustainability of the food and agriculture sector.

Both *ex situ* and *in situ* conservation will need further support to guarantee the availability of genetic diversity needed for future generations to adapt to climate change. *In situ* and on-farm conservation measures will need to guarantee the dynamic evolution of genetic diversity to changing conditions. However, there will be regions and species for which the rate of change caused by climate change may be greater than the natural capacity of certain species and populations to adapt or move, and human intervention will be needed to prevent accelerated genetic erosion, in particular through *ex situ* conservation. However, *ex situ* conservation should be considered a complementary strategy to *in situ* conservation and not substitute for it. The challenge is how to develop an overall integrated approach to conservation and use which will be cost-effective and, at the same time, safeguard as much diversity for the future as possible throughout climate change.

The sustainable use of genetic resources for food and agriculture is the foundation for many of the climate-change adaptation strategies required in food and agriculture. Farmers and rural communities will require genotypes adapted to multiple new stresses, from drought to new pests and diseases. On-farm management of genetic diversity has traditionally allowed farmers to cope with adversity. Breeding is a long-term process, so preparing to adapt to climate change requires planning. Given that climate change will increase the frequency of extreme climate events, measures should be taken to rehabilitate agricultural systems with locally adapted genotypes after disasters.

With climate change, countries will increasingly depend on genetic resources from other countries and regions to adapt their food and agriculture. Loss of genetic diversity at a given place may have negative effects globally as well as locally, as important traits for climate change adaptation may be lost forever. Interdependence between countries with regard to genetic resources for food and agriculture will increase, as will the need to improve the exchange mechanisms for this critical resource. In developing countries, lack of human and financial resources will impede response to climate change through the conservation and sustainable use of genetic resources for food and

agriculture. International cooperation, therefore, will be a key element of a long-term strategy to confront climate change in this field.

Suggestions for future action

- Analyze the effects of climate change, in particular in centres of origin and diversification of genetic resources of relevance to food and agriculture, to inform national conservation strategies.
- Improve monitoring methods of genetic resources being managed *in situ*, to increase understanding of threats and vulnerability due to climate change.
- Promote the collection and *ex situ* conservation of genetic resources for food and agriculture most threatened by climate change, and most potentially useful in adaptation.
- Develop robust programmes and strategies for sustainable use of genetic resources for food and agriculture, so that breeders, farmers and rural communities can have available a wide range of genetic diversity to adapt to climate change.
- Support farmers to continue developing locally adapted genotypes through on-farm management.
Improve rehabilitation strategies after climate-change related disasters to ensure that locally adapted genotypes are re-introduced.
- Integrate climate change dimensions into the relevant international policies and programmes for the conservation and sustainable use of genetic resources for food and agriculture, and the fair and equitable sharing of the benefits arising out of their use.
- Strengthen international cooperation to build capacities in developing countries to conserve and sustainably use genetic resources for food and agriculture to respond to climate change.

Appendix 1: Loss of genetic diversity at a time of climate change

<p>Plant genetic resources</p>	<p>In the next 50- 100 years, changing climatological conditions in farming systems will need to be matched with adequate responsive plant germplasm. The rate of change suggests that in many instances current locally available genetic material will not be adapted to the new conditions, resulting in genetic erosion. Farmer communities and countries will require continuous access to plant genetic resources to adapt their local crops.</p> <p>Crop wild relatives are a vital source of genetic diversity that can be used to adapt crops to future needs. However, the survival of crop wild relatives themselves is under threat from the impacts of climate change. Distribution modelling of wild relatives of three major food security crops (peanuts, cowpea and potato) suggests that by 2050:</p> <ul style="list-style-type: none"> • 16-22% of wild species will be threatened by extinction; • potential range size will be reduced for 97% of species with most of them losing more than 50% of their range size; • for one species, more than 50% of wild relatives are predicted to go extinct.⁶ <p>Local extinctions caused by climate change of useful wild plants gathered by rural communities for food, health, clothing or shelter, will have negative impacts on their livelihoods.</p>
<p>Animal genetic resources</p>	<p>Livestock diversity adds resilience to agricultural production systems. Human drivers of change in agricultural systems are leading to major and rapid loss of animal genetic diversity potentially putting more than one third of breeds at risk globally. This is particularly worrying in case of climate change, as breed loss may lead to genetic erosion of important fitness and adaptation traits.⁷</p> <p>Temperature increase, with reduced precipitation in many regions, will result in reduction of livestock reproduction and production as a result of heat stress. Increases in the frequency of droughts, floods and disease epidemics will increase the risk of losing entire breeds and populations that have a limited geographic distribution. Increases in the price of feed, energy and water may force a shift to less intensive management systems, requiring improvement of local low-input low-output animal breeds.</p> <p>Climate change is also expected to create additional challenges, such as new diseases, indicating the use of genetic diversity will become more important in future breeding improvement programmes.</p>
<p>Forest genetic resources</p>	<p>The impact of climate change on forest genetic resources will vary upon regions and will be species dependent. Different biological processes will take place contemporaneously: adaptation; migration and competition with existing species; population decline; extinction or survival in specific ecological niches. Species natural capacity to adapt will depend on their plasticity, provided by genetic diversity, and on possible introgression of adapted genes via geneflow, which depends on connectivity among ecosystems.</p> <p>In many cases, the rate of natural adaptation will be slower than the rate of change driven by climate shift, and human interference (conservation and sustainable use) will be essential for adaptation.</p>

⁶ Jarvis, A., et al. 2008. *The effects of climate change on crop wild relatives*, Agric Ecosyst Environ.

⁷ FAO. 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*. Rome (Italy).

	<p>In tropical species, climate change will affect species reproductive and seed dispersal mechanisms adding to the negative effects caused by other drivers of loss of forest genetic diversity.</p>
<p>Aquatic Genetic Resources</p>	<p><i>Inland waters:</i> About 20% of the world’s freshwater fish species have been listed as threatened, endangered or extinct in the last few decades⁸. The effects of climate change on wetland species are considered to be additive to the impacts of other drivers of biodiversity loss. The impact of climate change on inland waters biodiversity was low during last century, but projections show that this impact will very rapidly increase in the near future⁹. Areas at most risk from climate change in Africa coincide with the centres of origin of globally important fish genetic resources for freshwater aquaculture.</p> <p><i>Marine waters:</i> climate change may affect oceans physics and chemistry (temperature, acidification, stratification, changes in currents,...), with potential impacts on fisheries biodiversity: migration routes will be affected; changes in transport of eggs and larvae, spring blooms and growing season; different structure and composition of fish communities; increase of invasive species; lower fisheries productivity. These changes may have, in certain regions, a big potential impact on artisanal fisheries species composition and sharing arrangements for commercial harvests. They will also affect negatively certain ecological niches which are important genetic reservoirs for fish stocks. If fisheries reduces the genetic diversity within and among populations of fished species, and alter suite of genetic strategies of fish communities, it may have a negative impact on stocks capacity to adapt to climate change.</p>

⁸ Millennium Ecosystem Assessment. 2005. Millennium Ecosystem Assessment: Ecosystems and Human Well-Being. Wetlands and Water. Synthesis. World Resources Institute, Washington DC (USA).

⁹ *ibid.*