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SUSTAINABLE AGRICULTURE AND THE SUSTAINABLE USE OF AGRICULTURAL BIODIVERSITY: CONCEPTS, TRENDS AND CHALLENGES

1. The Executive Secretary is circulating herewith, for the information of participants of the fourteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, this note on sustainable agriculture and the sustainable use of agricultural biodiversity: concepts, trends and challenges, as submitted by Bioversity International. The note is circulated in the form and language in which it was received by the Secretariat.

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SUSTAINABLE AGRICULTURE AND THE SUSTAINABLE USE OF AGRICULTURAL BIODIVERSITY: CONCEPTS, TRENDS AND CHALLENGES

An information note submitted by Bioversity International for the Fourteenth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity, 10-21 May 2010, Nairobi, Kenya

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EXECUTIVE SUMMARY

Part of the scope of this paper was to assess the applicability of the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity (AAPG) to agricultural sustainability. In the course of assessing the AAPG, and clarifying the conceptual confusion around "sustainable agriculture" and "sustainable use of Agricultural Biodiversity" (AgBD), it was felt that the scope of the paper should go beyond the original assignment and, rather than just re-interpret the AAPG for agricultural application, describe the concrete action and policy priorities necessary to achieve the dual goals of significantly increasing global agricultural output and reducing the environmental footprint of agriculture over the next decades.

This paper interprets "sustainable use of AgBD" as all uses of AgBD that contribute to its conservation and perpetual availability as an input to agriculture. "Sustainable agriculture" is a different concept and interpreted as the ability of farmland to produce food and other agricultural products to satisfy human needs indefinitely as well as having sustainable impacts on the broader environment. Sustainable agriculture is a broad issue. It includes considerations of productivity goals, environmental stewardship, farm profitability and rural welfare objectives as well as consumer health. AgBD is a component of agriculture, and as such it cannot be equated with agriculture. Some principles underpinning sustainable agriculture will apply to enhanced or sustainable use of AgBD. However, the links between sustainable use of AgBD and sustainable agriculture may not always be straightforward. The use or deployment of AgBD can be of strategic importance in making agriculture more sustainable, but sustainable agriculture will depend on a range of other management components, notably nutrient, pest and disease management.

In contrast to the ecosystem services upon which agriculture relies, concerns of over-exploitation do not directly apply to many components of AgBD, for the biological diversity embodied in crops and animals is perpetuated as agricultural seeds and reproduced animals. The term "sustainable use" conjures the notion of the need for reconciling conservation and use of AgBD as somehow antagonistic goals when indeed conservation of AgBD, particularly of plant and animal genetic resources is only possible through use, and benefits arising from its actual or potential use provide the only incentive for its conservation. The principal threat to AgBD is ultimately not over-use but rather the under-use in agricultural systems and breeding programs.

A distinctive feature of the use of AgBD vis-à-vis the use of biodiversity in natural ecosystems is that agricultural practice typically requires trade-offs between the on-farm diversity and livelihood and development goals, particularly at the plot and farm level. Productivity needs and crop uniformity requirements arising from crop and post-harvest management as well as market integration all tend to reduce AgBD in agricultural systems. Trade-offs vary in intensity, or may not be observed in exceptional situations, but they need to be recognized as a reality that is unlikely to go away, particularly against the background of continued population growth, and the need to meet development and poverty alleviation goals.

The analysis of the 14 AAPG showed that they represent a valid general framework for AgBD with important messages targeted to a global audience. They are broadly applicable to agriculture in general and to a lesser extent to the sustainable use of AgBD in particular. However, they are stated in very general terms, and their wording and the accompanying rationales reflect concerns about the sustainability of use of non-agricultural biodiversity. In order for the AAPGs to be of operational value in agriculture and provide meaningful guidance for improved management they would need considerable re-interpretation.

A literature review and extensive internet search unveiled a large number of existing normative agricultural frameworks, principles and guidelines, aimed at greater sustainability of particular agricultural sub-sectors (e.g. EU Regulation on Organic Agriculture; Sustainable Cocoa; IFOAM principles; Good Agricultural Practice Principles). By comparing these frameworks with the AAPG, it was found that these offer more specificity in terms of thematic focus and target audiences, and greater

potential to guide priority action suited to particular circumstances of the highly diverse agricultural systems. These frameworks also represent good models for the development of production principles or standards for agricultural sub-sectors for which such principles do not yet exist. It is suggested that these sustainability frameworks be "marketed" and used to a larger extent. If more widely applied, they have the potential to move agriculture toward a more sustainable future.

In none of the frameworks of sustainable agriculture inspected more closely for the present information note were found references to the AAPG, clearly showing that they have not been used in shaping or inspiring the thinking about sustainable agriculture, a conclusion consistent with the observation that the fourth CBD national reports are largely silent on the AAPG. It is concluded that, in the field of agriculture, the AAPG offer no real added value over existing and more relevant conceptual frameworks other than re-affirming them. These other frameworks are fully compatible with the CBD. Agriculture has no shortage of sustainability principles and guidelines, but judging from its environmental footprint, certainly lacks their implementation.

Conceiving a sustainability framework for agriculture is a laudable pursuit, but in view of the complexity of agriculture and divergent local conditions and societal preferences, identifying a set of universal principles that have global validity, may prove elusive, or be so general as to be of little practical value. Sustainability implies the use of resources at rates that do not exceed the capacity of ecosystems to replace them. By definition, dependency on non-renewable inputs is unsustainable, even if in the short term it may be necessary as part of a trajectory toward sustainability. There are many difficulties in making sustainability principles operational. Over what spatial scale should agriculture be sustainable? Clearly an overarching goal is global sustainability, but should this goal also apply at lower levels, such as regions, nations, or farms? Could high levels of consumption or negative externalities in some regions be mitigated by improvements in other areas, or could some unsustainable activities in the food system be offset by actions in the non-food sector (through carbon-trading, for example)? Rather than focusing on principles, it is suggested, that the vast knowledge generated in recent decades about concrete options to increase production efficiencies and to reduce the environmental footprint of agriculture be put in practice.

There is no simple solution to sustainably feeding a world population that is expected to plateau at 9 billion people, especially as many become increasingly better off and converge on rich-country consumption patterns. A broad range of options need to be pursued simultaneously. A common, though erroneous, assumption about agricultural sustainability is that it implies a net reduction in input use, which would make such systems essentially extensive and would require more land. Neither of the two paradigms of agriculture being widely promoted in an antagonistic manner, the local and organic systems *versus* globalized and industrialized systems, alone can fully meet human needs. Organic agriculture teaches important lessons about soils, nutrients and pest management. And local agriculture connects people back to their food system. Unfortunately, certified organic food provides less than 1 percent of the world's calories, mostly to the wealthy. It is hard to imagine organic farming scaling up to feed 9 billion. Conventional and industrialized agriculture have benefits of economic scalability, high output and low labour demands. Organic and conventional agriculture should not be seen as contradictions, or intrinsically "good" and "bad" for agricultural sustainability, but as complementary sources from which the best elements should be borrowed and applied in appropriate contexts.

Experience shows that production can indeed be intensified (meaning more production per unit area) whilst reducing inputs and lowering the environmental footprint of agriculture. Intensification and environmental sustainability are not necessarily incompatible. Limited potential for the expansion of cultivated lands and the need to roughly double agricultural production over the next decades leave no alternative but to further improve the productivity of existing agricultural lands in a rather dramatic fashion. Agricultural intensification will have to be achieved by boosting land, water, nutrient and labour productivity, while at the same time avoiding the environmental degradation caused in the past by wasteful resource and input use. Sustainable intensification, as this process is called, will take place under conditions of increasing resource scarcity and climate change.

There is much potential for improved nutrient and water management, and for the reduction of greenhouse gas emissions from crops and livestock, but the lack of progress in implementing known technologies is discouraging. The need for more efficient nutrient use is particularly urgent in the case of phosphorus, because the known reserves of economically available phosphate rock are predicted to be depleted in the next 50-100 years. Phosphorus scarcity needs to be placed on the priority agenda for global food security. It illustrates that achieving full agricultural sustainability will require closing nutrient cycles through the full recovery of human excreta for use as fertilizer, and thus requires appropriate urban planning of sewage systems.

AgBD underpins agricultural productivity and is therefore of critical importance to contribute to agricultural sustainability. Much progress has been achieved in recent years with the *ex situ* conservation of major crops, and a multilateral access and benefit scheme has been established within the framework of the International Treaty of Plant Genetic Resources for Food and Agriculture. However much remains to be done to establish an efficient global conservation system. Local crops and the role of intra-specific crop diversity for dietary diversification and ecosystem health need to receive more attention in research and conservation efforts, particularly *in situ*. Animal genetic resources are at even greater peril. Around 20% of nearly 8000 livestock breeds are at risk. Of even greater concern is that during the first six years of this century 62 breeds became extinct – amounting to the loss of almost one breed per month.

Of the many potential supportive policies toward agricultural sustainability, the following deserve particular attention: **1) Encouraging resource-use efficiency** is the key to lessening the environmental impact of crops and livestock. There is evidence that water and nutrient use efficiency can be raised by a factor of 2-4 in intensive systems; **2) Correcting for negative environmental externalities of agriculture** will reflect the true costs of agricultural products. Costs for environmental damage will have to be passed on to consumers. This is thought to impact on the avoidance of waste, and on dietary change towards food of lesser environmental impact; **3) Rewarding farmers for the provisioning of environmental services** will provide incentives for farmers to engage in environmentally beneficial practices. Payment schemes for environmental services are currently under study, also in the context of the conservation of AgBD; **4)** The need for **increasing investments in agriculture and agricultural research** cannot be overstated. The development of technological innovations and the knowledge underpinning policy decisions as well as infrastructure improvements will require unprecedented research and development efforts. **5) Empowering poor farmers** that contribute most agricultural produce in developing countries will require a host of policies: revamping extension services, ensuring smallholders' land tenure, providing market access, and strengthening the productive capacities of women.

1. INTRODUCTION

1. At its ninth meeting, in paragraph 32 of its decision IX/1, the Conference of the Parties requested the Executive Secretary to collaborate with the Food and Agriculture Organization of the United Nations and other relevant organizations to further elaborate the operational guidelines of the Addis Ababa Principles and Guidelines (AAPG) for the sustainable use of agricultural biodiversity (decision VII/12, annex II), taking into account the special nature of agricultural biodiversity, its distinctive features, and problems needing distinctive solutions. The present note also aims to contribute to the in-depth review of sustainable use of biodiversity including agricultural biodiversity, as mandated by COP decision VIII/10, annex II.

2. The intention of the paper is to address the following questions:

i. To what extent are the AAPG applicable to AgBD?;

ii. How do the AAPG relate to other approaches and conceptual frameworks for sustainable use of AgBD?;

iii. What is the added value of the AAPG in relation to AgBD?;

iv. What is the trend in sustainable use of AgBD?; and

v. What policies, strategies, methodologies are being used to ensure sustainable use?

3. In preparing this paper it emerged that CBD sources, especially those concerned with the AAPG, use the terms “sustainable agriculture” and “sustainable use of AgBD” as synonyms, a practice causing considerable confusion when pondering the applicability of AAPG, for the two concepts are quite distinct. This prompted the writing of the Section “Concepts”, which attempts to “dissect” the two concepts. It also includes a description of “organic agriculture”. This topic frequently surfaces in the third and fourth CBD national reports, indicating much global interest in more sustainable agriculture, but it is often presented in a cursory manner and in simplified terms as if it was a “silver bullet” for achieving sustainability. Section “Concepts” may seem as a somewhat arbitrary selection of issues, but it appears that these need more reflection in the CBD.

4. The middle section assesses and asserts the applicability of the AAPG to agriculture and (partially to) AgBD. A literature review and an extensive internet search undertaken in the course of that work, however, brought to light a considerable number of normative frameworks and sustainability principles and guidelines for agricultural sub-sectors. Much of this section examines how these frameworks relate to the AAPG. One important conclusion from this analysis is that there is no shortage of sustainability principles in agriculture. They are actually better suited –if implemented- to bring about greater agricultural sustainability than the agricultural adaptation and re-interpretation of the AAPG whose conceptualization clearly betrays a predominant concern with non-agricultural biodiversity, and therefore cannot do justice to the distinct nature of AgBD.

5. Going beyond this critique of the AAPG the third and largest section of the paper describes the way forward to achieve agricultural sustainability through concrete measures and innovation. First, the challenges resulting from the growing demand for agricultural products and the need for sustainable intensification are substantiated. Then, the potential for reducing the negative environmental impact of agriculture and increasing the use of AgBD is presented. The paper concludes by compiling what currently appear to be the most promising policies to reconcile the need for more agricultural output with greater environmental stewardship.

2. CONCEPTS

2.1. Agricultural biodiversity

6. The CBD defines agricultural biodiversity (AgBD) as "all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agro-ecosystem: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes.."[1].

7. Agricultural systems are very complex and for proper functioning rely not only on the biodiversity of agriculturally used areas but also on the services of biota from the wider agricultural environment (e.g. pollinators, crop wild relatives). Broadly speaking, AgBD can be subdivided in two major categories that share a number of properties (also see Table 1).

8. The first category consists of the genetic resources for food and agriculture (GRFA)[2] that provide food and other essential harvested products from domesticated crops, crop wild relatives (CWR), domestic animals (including fish and other managed aquatic animals), fungal and microbial genetic resources (the latter particularly for post-harvest processes). GRFA have been the traditional focus of most of the work on AgBD for a number of reasons. The genetic resources embodied in agricultural seed and animal stocks are the most important assets of agricultural systems to deliver their principal ecosystem service, which is the provision of food and other agriculture-based commodities. As such they have overwhelming importance for human nutrition, dietary diversity and farmer income and economies. Moreover, the domestication of crops and livestock is inextricably linked to human intervention and management, and they have cultural and aesthetic significance. In response to genetic erosion, and because of the dependence of GRFA on human management, *ex situ* conservation efforts have focused on GRFA.

9. The second category of AgBD comprises all those non-harvested components that contribute to, and sustain, agricultural productivity by provisioning supporting and regulating ecosystem services. This is attracting growing attention to the extent to which the continued intensification and industrialization of agriculture is being questioned on sustainability grounds. The most significant organisms of this category of AgBD include soil micro-biota, pollinators and the antagonists of pest and diseases. Soil micro-biota are of immense diversity, and perform a number of vital functions that regulate soil fertility through the decomposition of litter and harvest residues and the cycling of nutrients such as nitrogen. Pollinators, both managed honey bees and the great diversity of wild pollinators, are essential for the production of a large number of crops, especially tree crops and horticultural species. Management of wild pollinators requires an ecosystem approach with boundaries of the system drawn beyond fields, into the broader agroecosystem. Finally, improved pest control is dependent on a diversity of natural enemies of pests from non-crop habitats (in addition to crop habitats) and the presence and survival of these biological control agents (predators, parasitoids) is essential for decreasing agriculture's current reliance on pesticides. Unlike GRFA, soil biota, pollinators and pest control agents are mostly not unique to agricultural systems, and their continued abundance and diversity in agricultural systems is more a utilitarian rather than conservationist concern.

1 COP V/5 Appendix, paragraph 1

2 For example the ITPGRFA defines [PGRFA] as "any genetic material of plant origin of actual or potential value for food and agriculture".

10. The previous paragraphs illustrate the complexity and multifaceted nature of AgBD in terms of the taxonomic groups involved (plants, animals, fungi, micro-organisms), the varying degrees of its reliance on human intervention, the occurrence in agricultural areas and the wider ecosystem, the type and importance of services AgBD components provide, etc. It is therefore probably more difficult to make generalized statements on the management or sustainable use of AgBD as compared with other types of biodiversity.

Table 1: Attributes of AgBD components

Attribute	**Crops**[a]	**Livestock breeds**[b]	**Crop wild relatives and gathered food**	**Soil biota**	**Pollinators**	**Diseases, pests and their antagonists**
Uniqueness in agric. systems	yes	yes	partial	no	no	partial
Principal contribution to ecosystem services	Provisioning food & agricultural products	Provisioning food & agricultural products	Food & agricultural products	Supporting soil formation, & nutrient cycling	food	Regulating pests and diseases
Relevance of intra-specific diversity to delivery of ecosystem services	high	high	high	low	low	high
Threats to intra-specific diversity	high	high	intermediate	low	?	?
Species richness	intermediate	low	high	very high	high	intermediate
Importance of *ex situ* conservation	high	high	high	low	low	low
Importance of *in situ* management	high	high	high	intermediate	high	high

a) crop varieties, landraces, breeding materials, b) including aquatic animals in managed inland fisheries

11. Further complicating the description of AgBD is the huge variation of agricultural systems. For example, management practices and AgBD use in an intensively cropped sugarcane production system for biofuel production are radically different from those in an extensively managed cacao agro-forest. Recommendations for best practices of sustainable use of AgBD need to take these differences into account and may therefore arrive at different or even opposing conclusions depending on the context of a particular agricultural system.

12. It is generally observed that greater diversity or complexity of agricultural landscapes is associated with greater diversity of all organisms that constitute AgBD, and the uniformization of traditional into intensively managed agricultural systems is accompanied with overall loss of AgBD. It is often argued that a more diverse agricultural ecosystem offers a shield against perturbations, natural or human-made, contributing to agro-ecosystem resilience. Greater AgBD may create “pest suppressive” conditions and greater resistance to invasion of farming systems by noxious species. It can provide protection against uncertainties in the market, especially for less capitalized producers (e.g. AnGR), and increase the opportunities to add value and exploit new markets (crop variants, neglected species). However, greater AgBD in terms of the variety of crops and breeds can also translate into a hindrance for the participation in markets that require standardized and uniform products.

2.2. Sustainability

13. In a broad sense, sustainability is the capacity to endure[3]. The concept is applied to ecosystems and human development efforts and its meaning is to a considerable extent contextual. Ecosystems are sustainable when they maintain ecological processes, functions, biodiversity and productivity into the future. For humans, sustainability is the potential for long-term maintenance of wellbeing, which will in turn depend on the responsible use of natural resources.

14. The Global Environment Outlook 4 (UNEP, 2005, p. 524-525) defines sustainability as "a characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs" thus capturing two fundamental issues: the intra-generational equity (meeting human needs now) and inter-generational equity (fulfilment of basic needs of all global citizens in the future; see also Orr 2006).

15. Sustainability is often defined as resting on three pillars or having three dimensions: environmental, social and economic sustainability. While some have argued the need to integrate these dimensions or redress the balance between them, others have pointed out the vagueness of the concept. Adams (2006) contrasts the hugely expanded awareness for sustainable development in recent years with the mounting evidence for the "global human enterprise becoming rapidly less sustainable" putting this down, in part, on the looseness of the concept and that it means different things to different people.

16. The conventional understanding of sustainable development, based on the 'three pillars' implies that trade-offs can be made between environmental, social and economic dimensions of sustainability. A distinction is often drawn between 'strong' sustainability (where such trade-offs are not allowed or are restricted) and 'weak' sustainability (where they are permissible) (Adams 2006). The concept of 'critical natural capital' is also used to describe elements of the biosphere that cannot be traded off (e.g. critical ecosystems). However, in practice, development decisions by governments, industries and other actors do allow trade-offs and have traditionally put greatest emphasis on the economy above other dimensions of sustainability. This is a major reason why the environment continues to be degraded and development does not achieve desirable equity goals (Adams 2006).

2.3. Sustainable agriculture

17. Agreement on a universally accepted definition of sustainable agriculture has proved to be elusive, given the extraordinary diversity and complexity of agricultural land use, and the perspective taken (producer, consumer, etc.). For the purpose of this information paper, sustainable agriculture is defined as *the ability of farmland to produce food and other agricultural products to satisfy human needs indefinitely as well as having sustainable impacts on the broader environment*. This requires agriculture to avoid severe or irreversible damage to the endogenous or external ecosystem services upon which it depends, notably soil fertility, irrigation water, genetic variability, pollinators, etc. and have acceptable impacts on the broader environment (environmental stewardship).

18. The principle of sustainability implies the use of resources at rates that do not exceed the capacity of ecosystems to replace them. By definition, dependency on non-renewable inputs is unsustainable, even if in the short term it is necessary as part of a trajectory toward sustainability. There are many difficulties in making sustainability operational. Over what spatial scale should food production be sustainable? Clearly an overarching goal is global sustainability, but should this goal also apply at lower levels, such as regions, nations, or farms? Could high levels of consumption or negative externalities in some regions be mitigated by improvements in other areas, or could some unsustainable activities in the food system be offset by actions in the non-food sector (through carbon-trading, for example)? Though simple definitions

3 The word "sustain" is derived from the Latin verb sustinere (to keep in existence or maintain) and implies long-term support or permanence

of sustainability are independent of time scale, in practice, how fast should we seek to move from the status quo to a sustainable food system? The challenges of climate change and competition for water, fossil fuels, and other resources suggest that a rapid transition is essential (Godfray *et al.* 2010).

19. It is for human societies to negotiate and decide the nature of the trade-offs involved in reaching global agricultural sustainability. Such considerations are difficult or impossible to capture in the definition of the concept, as trade-offs may change with scale, time, societal preferences, internationally agreed targets, etc.

20. There is a growing portfolio of enhanced agricultural practices that farmers can use to make agriculture more sustainable, for example those resulting in greater nutrient and water efficiencies, targeted plant protection (see section 4.2). However, it is argued that improved farming practices are only a part of the solution. Despite the insight that the biosphere is limited, the richer part of humankind manifestly fails to adjust consumption to the biosphere's limits. Continued physical expansion of commodity supply systems means that rich consumers in developed and developing countries continue to perceive resource flows as bountiful, and develop no sense of limits to consumption. Few consumers show awareness of production systems as ecologically constrained. Belief in the opportunity to consume without limits in an ecologically limited world is a global risk. Adams (2006) argues that politicians fear backlash from citizens reacting as consumers to anything that alters their lifestyle in ways they perceive as adverse. This results in demands for low fuel prices, profligate material and energy consumption, ignorance and/or disregard of the social and environmental conditions under which global products are created.

21. It is also well established (and implicit in some definitions of sustainable agriculture) that prices for agricultural inputs and outputs do not account for their true environmental cost and result in market failure. Farmers operate in economic and regulatory frameworks and such frameworks determine to a large extent whether farmers can engage in more sustainable practices.

2.4. Sustainable use of agricultural biodiversity

22. CBD texts and commentaries use the terms "sustainable use of agricultural biodiversity" and "sustainable agriculture" interchangeably suggesting synonymous meaning of these overlapping but different concepts. As described in the previous section, sustainable agriculture is a broad issue which includes considerations of productivity goals, environmental stewardship, farm profitability and rural welfare objectives as well as consumer health. AgBD is a component of agriculture, and as such it cannot be equated with agriculture. Some principles underpinning sustainable agriculture will apply to enhanced or sustainable use of AgBD. However, the links between sustainable use of AgBD and sustainable agriculture may not be always as straightforward as they are occasionally perceived. For example, well-managed agricultural systems can be relatively poor in AgBD and yet provide ecosystem services in the broadest sense (food, nutrient cycling, sustainably managed soil biota and pollinators) (Wood and Lenne 2005). Conversely, economically or environmentally unsustainable agricultural systems can be rich in AgBD (e.g. "organically"-certified systems that deplete soil nutrients). Most tellingly, work on agricultural sustainability and certification standards of "organic" production methods are often remarkably silent on AgBD implications, especially in reference to the management of intra-specific crop diversity.

23. In other words, the use or deployment of AgBD can be of strategic importance in making agriculture more sustainable, but sustainable agriculture will depend on a range of other management components, notably nutrient, pest and disease management, etc. Statements that refer to "sustainable agriculture" and "sustainable use of agricultural biodiversity" at the same time must necessarily have blurred meaning. In this paper, the two concepts are diferentiated.

24. Definitions of sustainable use relative to ecosystems or particular biological resources (fish stocks, forest products) generally reflect the concern over the widely observed excessive consumptive use of biological resources leading to levels below critical thresholds, beyond which their long-term viability or very existence is put in jeopardy[4]. However, concerns of over-exploitation of a resource do not directly apply to AgBD, for the biological diversity embodied in crops and animals is perpetuated as agricultural seeds and reproduced animals. The term "sustainable use" conjures the notion of the need for reconciling conservation and use of AgBD as somehow antagonistic goals when indeed conservation of AgBD, particularly of PGR and AnGR, is only possible through use, and benefits arising from its actual or potential use (or value) provide the only incentive for its conservation. The principal threat to AgBD is ultimately not over-use but rather the under-use in agricultural systems and breeding programs. "Sustainable use" is a concept rarely used in the AgBD community, which prefers to speak of the "management", "deployment" or "enhancement" of genetic resources (Rischkowsky 2008).

25. A distinctive feature of the use of AgBD *vis-à-vis* the use of biodiversity in natural ecosystems is that agricultural practice typically requires trade-offs between the on-farm diversity and livelihood and development goals, particularly at the plot and farm level. Productivity needs and crop uniformity requirements arising from crop and post-harvest management as well as market integration all tend to reduce AgBD in agricultural systems. Trade-offs vary in intensity, or may not be observed in exceptional situations, but they need to be recognized as a reality that is unlikely to go away, particularly against the background of continued population growth, and the need to meet development and poverty alleviation goals. In general such trade-offs have lead, and continue to lead, to diminished overall crop and animal diversity in agricultural systems, causing genetic erosion, which provides the rationale for *ex situ* conservation.

26. This is not to say that current trade-offs should be taken for granted. The improved management of agro-ecosystems can result in greater crop and ecological diversity of production areas. Agricultural and trade policies need to be amended to mitigate trade-offs rather than accentuate the decline of on-farm maintenance of crop and animal diversity as is currently the case[5]. Even markets, particularly emerging demands for highly differentiated products, can provide incentives for greater use of AgBD.

27. Based on the above considerations, and for the purpose of this information paper, "sustainable use of agricultural biodiversity" is defined as *"all uses of AgBD that contribute to its conservation and perpetual availability as an input to agriculture*".

2.5. Organic agriculture

28. Unease over agriculture's growing reliance on pesticides and synthetic fertilizers led to the emergence of the "organic" movement starting in the 1940s. There is a variety of organic schools and philosophies, but they all eschew the use of synthetic fertilizers and pesticides, herbicides, plant growth regulators, genetically modified organisms and livestock feed additives. To replace these inputs, organic farming relies on crop rotation (in particular using nitrogen-fixing legumes), the use of manure, composting, mechanical cultivation and biological pest control. Consumer demand for organic food is very much driven by the notion of the purportedly superior quality and safety of organic food (a claim not borne out by a recent meta-study, see Dangour *et al.* 2009). However, the rationale for organic production methods goes far beyond consumer concerns about healthy food, to include reducing the ecological "footprint" of

4 For example, the CBD defines sustainable use in article 2 as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations."

5 Examples: 1) seed and seed systems policies unsupportive of informal seed systems and on-farm crop diversity; 2) trade and food safety policies that discriminate against neglected crops; 3) pricing in of externalities in the prices of agricultural products.

farmed areas through managing nutrient cycles, protecting pollinators and beneficial micro-organisms, maintaining healthy soils and conserving water.

29. Organic farming practices are regulated, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM[6]). For farmers to obtain on the market the price premiums for organic produce, they need certificates that require farm audits to prove compliance with organic production standards.

30. In 2007, agriculture certified as "organic" covered some 32 million hectares or 0.8% of total global farmland[7]. However, the *de facto* area of organic agriculture is much larger, if traditional agricultural systems that largely are in conformity with IFOAM standards but not certified, would count as such. Much subsistence farming, some slash and burn farming, traditional pastures and cacao production, *inter alia*, are overwhelmingly "organic", not necessarily by intent but rather because of the unavailability of farm-external inputs.

31. Modern organic farming has been much more influential than its share of total farmland would suggest. The long-standing controversy surrounding the benefits of "organic" versus "conventional" farming has drawn awareness to the problems associated with 'chemical-happy' farming. Where substantiated by scientific methods, principles of organic farming have been assimilated by the "integrated" nutrient and pest management methods that are now standard repertoire of conventional agriculture. Conventional farming uses extremely varied methods and modes: mixed or stockless farms, dairy or arable, intensive or extensive, no-till or minimum-tillage, mono-crops or mixed crops. It is therefore not quite appropriate to portray conventional or mainstream farming as diametrically opposed to organic farming.

32. A review of comparative studies of the two systems by Holea *et al* (2005) identified a wide range of wild taxa that benefit from organic management through increases in abundance and/or species richness. It also highlighted three broad management practices (prohibition/reduced use of chemical pesticides and synthetic fertilizers; sympathetic management of non-cropped habitats; and preservation of mixed farming) that are intrinsic (but not exclusive) to organic farming, and that are particularly beneficial for farmland wildlife. However, the review remained inconclusive as to whether a 'holistic' farm approach (i.e. organic) provides greater benefits to biodiversity than carefully targeted prescriptions applied to relatively small areas of cropped and/or non-cropped habitats within conventional agriculture. It further concluded that many comparative studies encounter methodological problems, limiting their ability to draw quantitative conclusions and that more research is needed to determine the impacts of organic farming, before a full appraisal of its potential role in biodiversity conservation in agro-ecosystems can be made.

33. There is much debate around the proposition by advocates of organic agriculture that it can contribute significantly to the global food supply. There is evidence in support of and against that proposition. Analysing a global dataset of 293 comparative studies, Badgley *et al*. (2007) found that yields from organic farming were slightly inferior to conventional low-input systems in developed countries, but the inverse was true for developing countries. The authors concluded that "organic methods could produce enough food on a global *per capita* basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base". Extrapolating from modeling results they further concluded that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertilizer currently in use.

6 IFOAM definition of organic agriculture: "Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

7 http://www.organic-world.net/graphs-2009.html

34. Others have dismissed the notion that organic farming could sustain a world population of 9 billion without substantially increasing the area dedicated to agriculture, arguing that biological nitrogen fixation and sources of manure are insufficient to increase agricultural productivity to meet future needs (Trewavas 2001, 2002). According to MEA (2005), the human population may have already exceeded the maximum number that can be supported without chemical fertilizers. In Sub-SaharanAfrica, where soils are mostly of poor quality and nutrient-depleted, and food production will have to meet the needs of a population 80% greater in 20 years than today, judicial application of P and N fertilizers appears to be inescapable if further soil mining and expansion of low-intensity agricultural areas through destruction of habitat is to be avoided (Smaling et al. 2006, Grenz & Sauerborn 2007, Henao 2002-quoted in MEA 2005, p.335-336).

35. The nature and quantification of nitrogen flows in agricultural systems is of considerable importance in the assessment of their sustainability. Nitrogen in the form of nitrate and ammonia is often the limiting factor in agricultural productivity, but because of leakage and gaseous loss, particularly under sub-optimal agricultural practices, has much negative environmental impact (MEA 2005). Organic nitrogen sources, such as livestock manure and legume cover crops used in organic production systems, can be a substitute to commercial nitrogen fertilizers. But these practices are not always feasible in the high-potential cereal production systems of developing countries, where population density is high and arable land resources are limited (Ali 1999).

36. Organic production systems that rely entirely on organic nitrogen sources are becoming more popular in Europe and North America. Organic systems are feasible, and even profitable, in these countries because people can afford to pay higher prices for their food, and there is adequate land to support the crop rotations, legume cover crops, and forages that are needed to supply adequate nitrogen. It is not clear, however, that environmental benefits would accrue from widespread adoption of organic agriculture if these systems were forced to produce as much grain as conventional systems do today, because it is just as difficult to control losses of nitrogen from organic sources as it is from nitrogen fertilizer (Cassman *et al.* 2003). Use of both organic or fertilizer nitrogen need not be an ‘‘either-or’’ decision. In most conventional systems, farmers use organic nitrogen sources and rotate with legume crops to minimize the need for nitrogen fertilizer when it is cost-effective to do so.

37. Avoidance of synthetic nitrogen fertilizers as mandated by organic standards certainly implies reduced emissions of greenhouse gases embodied in nitrogen fertilizers. But biological N fixation has also been harnessed by mainstream agriculture. Worldwide plantings of N-fixing crops, such as soybeans, now capture about 40 million tons of nitrogen a year, an ecosystem service worth several billion dollars annually in avoided fertilizer costs (MEA 2005). However, the negative consequences from biological N-fixation are ultimately similar to those resulting from industrial N fixation: increased emissions of N_2O and leaching of N from the land into water bodies once organic N has been mineralized (MEA 2005).

38. A recent comparative study in the United Kingdom has shown that the carbon foot print of milk (per litre) is only slightly smaller in organic dairy farming, owing to the fact that emissions of methane from enteric fermentation and nitric oxide from soils and manure accounted in both farms for most of greenhouse gas emissions (in terms of CO2 equivalents) (Plassmann & Edwards-Jones 2009).

39. It is interesting to note that the Haber–Bosch process in which atmospheric nitrogen is fixed and used to manufacture synthetic nitrogen fertilizer does not necessarily require the use of fossil fuel. If coupled to renewable energy sources the process has the potential to provide unlimited supplies of climate-neutral nitrogen fertilizer. The use of synthetic fertilizers in the future could therefore be perfectly compatible with sustainable agricultural practices.

40. It has also been argued that the categorical opposition of organic agriculture to GMOs is unreasonable[8], where these have the potential to contribute, in a complementary manner to other approaches, to the much needed agricultural intensification and resource-use efficiency (Fedoroff *et al.* 2010; see also section 4). For example, reviewing the findings of a number of studies on the use of transgenic cotton in India, Morse *et al.* (2005) concluded that insecticide use against ballworms was greatly reduced in insect-resistant BT cotton as compared to non-BT cotton. In addition, BT cotton also provided substantial benefits to farmers in terms of increased gross margins (39% and 63% higher vis-à-vis non-BT cotton). It would also seem unreasonable to ignore transgenic technologies, particularly if funded and owned by the public sector, that make crops more nutrient-efficient and productive, and food more nutritious (Trewavas 2002, Good *et al*. 2007, Gregory et al. 2009). Godfray *et al*. (2010) therefore contend that "genetic modification is a potentially valuable technology whose advantages and disadvantages need to be considered rigorously on an evidential, inclusive, case-by-case basis: Genetic modification should neither be privileged nor automatically dismissed."

41. The demand for organic food continues to grow fast although it is more expensive than conventionally produced food[9]. The fact that consumers are willing to pay farmers a premium to do what they perceive as the "right thing" is encouraging, but still limited to relatively wealthy consumers in rich countries who spend a small part of their income on food. However, Capper (2009) shows that consumers often are mislead in thinking they are making virtuous food choices, when, in truth, they are supporting production practices that consume more natural resources, cause greater pollution and create a larger carbon footprint than more efficient, technology-driven, conventional methods.

42. Likewise, 'locally grown' food is thought to have a lower environmental impact than food transported over long distances due to carbon emissions from fuel used in transport. However, it is incorrect to assume that the distance that food travels from point of origin to point of consumption is an accurate reflection of environmental impact. This simplistic approach fails to consider the productivity of the transportation system, which has tremendous impact on the energy expended per unit of food. As an example, one dozen eggs, transported several hundred miles to a grocery store in a tractor-trailer that can carry 23,400 dozen eggs is a more fuel-efficient, eco-friendly option than a dozen eggs purchased at a farmers' market (4.5 times more fuel used) or local farm (17.2 times more fuel used). Instead, it is life-cycle assessments, which evaluate all inputs and outputs within the food-production system that allow correct comparisons of different production systems (Capper 2009).

43. In conclusion, organic and conventional agriculture should not be seen as contradictions, or intrinsically "good" or "bad" for agricultural sustainability, but as complementary sources from which the best elements should be borrowed and applied in appropriate contexts.

3. THE ADDIS ABABA PRINCIPLES AND GUIDELINES FOR THE SUSTAINABLE USE OF BIODIVERSITY IN RELATION TO AGRICULTURE

44. This section examines the relevance and the status of implementation of the AAPG in reference to the sustainable use of agricultural biodiversity and sustainable agriculture. In particular it aims to answer the following questions:

8 New Scientist 12 Sep 2009 "Learn to love genetic engineering"

9 http://www.ifoam.org/sub/faq.html

i. To what extent and how have the AAPG been used to achieve greater agricultural sustainability and sustainable use of agricultural biodiversity?; and

ii. What is the added and operational value of the AAPG *vis-à-vis* other normative frameworks related to the sustainable use of agricultural biodiversity?

3.1. Background

45. The sustainable use of the components of biological diversity is one of the three objectives of the Convention (Article 1) as well as being the subject of Article 10. The AAPGs reflect the spirit of Article 10 in the context of agricultural biodiversity defined under the Convention as: a broad term that includes all components of biological diversity of relevance to food and agriculture (see section 2.1.). Stakeholders anticipated in Article 10 are central in the Principles and Guidelines, such as national governments, "local population" (local and indigenous communities in the Principles and Guidelines) and "private sector".

46. The Addis Ababa Principles and Guidelines consist of 14 practical principles, each of which is composed of the principle, the underlying rationale and several operational guidelines. Information note UNEP/CBD/SBSTTA/13/INF/4 provides an overview on the history of discussions of sustainable use in the framework of the CBD, in particular decisions IV/16 (annex II), V/24, VI/13, culminating in the adoption of the AAPGs (decision VII/12 annex II).

47. In adopting the AAPG, reservations were expressed regarding its application to the agricultural biodiversity programme of work, and further consideration was called for. The Conference of the Parties requested the Subsidiary Body on Scientific Technical and Technological Advice to explore the applicability of these principles and guidelines to agricultural biodiversity. Paragraph 3 of the preamble to the AAPG, indicates that agricultural biodiversity was not fully addressed in the process, and a need was identified "for further elaboration specifically with respect to domesticated species, breeds and varieties in the context of the programme of work on agricultural biodiversity".

48. According to an analysis in information note UNEP/CBD/SBSTTA/13/INF/4 cross-referencing the AAPGs with the CBD programme of work on agricultural biodiversity shows that all the principles are compatible with the PoW. It highlights the synergy between the two frameworks and concludes that "Parties are largely in line with the Principles and Guidelines if they are implementing the activities from the programme of work".

3.2. Application of the AAPGs to agriculture

49. Table 2 provides an overview on the 14 AAPGs and some of their attributes. The principles can be broadly assigned to 4 larger thematic groups, which resonate with the biophysical and social dimensions of the concept of sustainability (see section 2.2). These groups pertain to a) environmental stewardship (principles 5 & 11), b) management of AgBD (4,7,9,13), c) supportive policies and institutions (1,3,6,8,10,14), and d) social equity (2,12). Grouping the AAPG into broader themes also seems to be justifiable in view of partial thematic overlap of principles.

50. The AAPGs are silent on specific target audiences, but from the statement of the principles and their accompanying guidelines we can deduce to whom each principle as "a normative rule or code of conduct" is directed (Table 2). All the principles need to guide and inform research and policy making. Certain principles, in particular those on environmental stewardship, are mainly useful to derive best practices for the users of agricultural biodiversity (farmers, livestock producers, herders, beekeepers, etc.), while others are relevant to consumers as the ultimate drivers of agricultural products.

51. The last two columns in Table 2 indicate the extent to which each principle is relevant to sustainable agriculture as well as to the sustainable use of agricultural biodiversity. All AAPG apply to sustainable

agriculture to various degrees, but it is difficult to see how AAPG 5, 7 and 11 can be interpreted to have meaning in the deployment of AgBD.

52. Clearly, the formulation of the AAPG has been inspired by considerations of non-agricultural biodiversity. Inspection of the reports from the four workshops leading up to the formulation of the AAPG shows that deliberations dealt only marginally, if at all, with agricultural biodiversity and participants were mostly representing environmental disciplines. The case studies presented at the workshops were overwhelmingly drawn from wildlife utilization (drylands, forest products, marine and freshwater fisheries).

Table 2. An overview on the 14 AAPGs and some of their attributes

Addis Ababa Principle (abbreviated)	**Sub-domain of sustainability**	**Audience targeted for implementing principle**				**Concerned mainly with**	
		Policy makers	**Scientists**	**Farmers**	**Consumers**	**Sustainable use of agric. BD**	**Sustainable agriculture**
AAP1: Supportive policies, laws and institutions are in place at all levels and there are effective linkages.	Supp. Pol. & Inst.	√√	√			√√	√√
AAP2: Local users of biodiversity should be empowered by rights to be accountable for use of the resources.	Social equity	√√				√√	√
AAP3: Policies that distort markets or represent perverse incentives for degradation should me removed or mitigated.	Supp. Pol. & Inst.	√	√			√	√√
AAP4: Adaptive management through science, traditional knowledge, and feedback from use and impact assessment.	Mgt-AgBD	√	√	√	√	√	√
AAP5: Avoidance of adverse impacts on ecosystem services and components.	Env. Stew.			√√	√		√√
AAP6: Support of interdisciplinary research into all aspects of use and conservation of biological diversity.	Supp. Pol. & Inst.	√	√√		√	√	√
AAP7: Spatial and temporal scales of management should be compatible with the ecological and socio-economic scales of the use and its impact.	Mgt-AgBD		√	√			√
AAP8: International arrangements for international cooperation where multi-national decision-making are needed.	Supp. Pol. & Inst.	√√				√√	√√
AAP9: Interdisciplinary, participatory approach for management and governance related to the use.	Mgt-AgBD	√	√	√		√	√

AAP10: Policies need to take into account use and non-economic values of biodiversity and market forces affecting the values and use.	Supp. Pol. & Inst.	√√	√			√√	√√
AAP11: Avoidance or minimization of waste and optimized benefits from uses.	Env. Stew.			√√	√		√√
AAP12: Local custodians of biological diversity need to benefit from the uses of these resources.	Social equity	√√	√	√		√√	√
AAP13. The costs of management and conservation of biological diversity should be internalized within the area of management and reflected in the distribution of the benefits from the use.	Mgt-AgBD	√√	√			√√	√√
AAP14. Implementation of education and public awareness programmes on conservation and sustainable use; more effective communication between stakeholders and managers.	Supp. Pol. & Inst.	√	√	√		√√	√√

Env. Stew.= Environmental stewardship
Mgt-AgBD= Management of AgBD
Supp. Pol.=Supportive policies and institution

53. The following paragraphs examine some of the AAPG more closely.

54. AAPG1 fully applies to agriculture and sustainable use of AgBD, but it is stated in such general terms it is difficult to see what its operational value is. There is a large body of literature on specific supportive policies to make agriculture more sustainable, and major issues in that regard will be examined in section 4.4. of this paper. There are also good examples for the implementation of AAPG1 with regard to the sustainable use of AgBD: the International Treaty on Plant Genetic Resources, which facilitates international access and benefit sharing of PGRFA. Another example is Decision 391 of the Andean Community and its implementation in relation to the International Treaty. Decision 391 and the International Treaty have very different approaches regarding access and benefit sharing, but a recent bill in Peru presents a compromise in the regional debate as to whether to apply the more restrictive rules of Decision 391 or the more flexible, multilateral approach offered by the Treaty. This is an example for resolving contradicting legislation between national law and internationally accepted responsibilities, as mentioned in the guidelines to the principle (Ruiz 2008).

55. As recognized by participants of the regional workshops, the wording of AAPG2 and its underlying rationale imply a bias towards protected areas, and there is a “need for modifications in applying it to agricultural biological diversity”. Farmers do indeed need to be empowered as the traditional custodians of AgBD, but for reasons that are rather different from those offered in the guidelines to AAPG2.

56. Rather than providing support to local users of AgBD to support accountability for sustainable use, farmers need compensation for their maintenance and *in situ* conservation of AgBD as an important, yet largely unappreciated, public good. Farmers also need support, encouragement and most importantly incentives for the maintenance of traditional AgBD.

57. The concept of “farmers’ rights” and the sizeable body of work on the feasibility of their implementation appear to offer a more useful framework to add meaning to principle 2 as it applies to

AgBD. For example, the ITPGRFA recognizes farmers' rights in article 9, with provisions regarding the protection of traditional knowledge, equitable benefit sharing arising from the use of PGRFA and participation in decision making on conservation and use of AgBD.

58. Progress with the implementation of farmers' rights on AgBD has, *inter alia*, been hampered by the problems involved in establishing legal ownership over particular genetic resources owing to problems with the definition of these resources and their being shared by communities, or even countries. In such cases, the protection of farm products through intellectual property rights in the way of geographic indications can provide interesting solutions and benefits for farmers. Geographic indications (GI, such as denomination of origin) have been highly successful in the re-valuation of traditional agricultural products in Europe.

59. AAPG3 is highly relevant to AgBD. In particular, regulations and laws in support of formal seed systems discourage, or discriminate against, the use of traditional landraces. In many countries, varieties that are not listed in official registries of accepted varieties are not permitted for commercial production, and are restricted to the realm of hobby gardening. In some cases seed registration laws prohibit the sale of seed not protected by plant variety protection laws. There are concerns that in countries joining the International Union for the Protection of New Varieties of Plants (UPOV) and enacting legislation that confer plant breeders' rights, the availability and access to local varieties may decrease.

60. In a similar vein, developing country seed legislation mostly ignores the importance of informally exchanged or traded seed, which may account for most if not all used agricultural seed in more traditional agricultural systems. Such "informal seed systems" are of critical importance to the on-farm conservation and further evolution of native diversity, and to rural livelihoods. More legislative support for informal seed systems is warranted, and encouraging project experiences and case studies can be identified to illustrate this point.

61. The stringent food safety assessment for novel foods required by the European Union's Novel Food Regulation (NFR) is another example for policies that have (unintentionally) undermined the sustainable use of AgBD. The NFR places a high burden of proof on those bringing traditional food products to the EU market not consumed in the EU prior 1997. The regulation has emerged as a non-tariff trade barrier for heritage foods from developing countries that are derived from native biodiversity and are viewed as "exotic" from the EU perspective (Hermann 2009).

62. Responses in the third country reports related to AAPG3 focused on positive incentive measures for providing support "to practise environmentally friendly agriculture". Presumably this relates to the still small but increasing share of certified agro-ecological production. However, ecological production standards concentrate very much on environmental concerns and target the non-harvestable AgBD (soil biota, pollinators, pest and disease regulation). They are largely silent on the need to conserve intra-specific diversity of native crops and breeds. Organic *quinoa* production in Bolivia is based on a single variety (*quinoa real*). Rainforest-certified coffee or cacao is mostly derived from genetically uniform plantations.

63. The wording of the statements of AAPG5 and AAPG11 as well as the underlying rationales are clearly inspired by considerations of the sustainable use of non-agricultural system, as seen by the references to forest cutting quotas and the management of wild shrimps populations in the guidelines of principle 5, as well as to extractive production methods of shrimp fisheries in principle 11. However, the two principles at hand fully apply to agriculture, in terms of the need for agriculture to minimize adverse impacts on the ecosystem services it relies on.

64. Because of the vast extension, and increasing intensification of agriculture, unsustainable agricultural practices not only adversely affect agricultural areas (e.g. soil erosion and salinization), but also to a growing extent adjacent ecosystems, through a variety of mechanisms such as nutrient (particularly

nitrogen) and pesticide effluents and leakage into water bodies, the elimination of habitats for non-agricultural biodiversity, greenhouse gas emissions, introduction of alien species.

65. Although there is no indication in the fourth national reports submitted under the CBD to suggest that a conscious application of principles 5 and 11 has shaped the debate about sustainable agriculture, the reports contain frequent examples for developments at the national level that illustrate the relevance of the ideas embodied in these closely related principles to agriculture.

66. AAPG4 is applicable to the sustainable use of AgBD and to agriculture as a whole as well. Adaptive management plays a central role in achieving agricultural sustainability. Ideally, farmers should constantly adapt their practices based on feedback from scientific findings. Integrating feedback and adaptive management between farmers and other key stakeholders in the agricultural sector is also central. One example is given by the case of plant breeders and farmers interacting in the development of new crop varieties using a system of participatory plant breeding.

67. The principle includes a provision for "suspension of unsustainable practices". Unfortunately, the understanding of what constitutes unsustainable practices, is often not available locally and more research is needed to establish remedial action. Even where required knowledge could be adapted to local conditions in a straightforward manner, the rural extension services required to deliver and communicate such knowledge to farmers are often weak, or non-existent, particularly in developing countries.

68. AAPG6 is fully applicable to AgBD, but so general as to be almost a cliché.

69. AAPG7 and its operational guidelines require considerable reflection to "tease out" intended meaning in relation to AgBD. Indeed, participants in the African Regional Workshop on Sustainable Use of Biological Diversity requested clarification of the intent of the principle, and more practical explanations about the application of it to agricultural biodiversity.

70. Commentary in the info paper of the Addis Ababa workshop suggests that principle 7 was inspired by ecosystem approach principles 2 and 7 and by considerations of the disconnect between users and managers of biodiversity. However, users and managers of AgBD are the same, namely farmers.

71. The application of AAPG8 to AgBD is very important, but again is fairly general. It fully applies to the interdependence of countries in terms of PGRFA and AnGR, as one of the attributes that makes AgBD so distinctive from other biodiversity. The historical reliance of agriculture on introduced crops and animal breeds (in all parts of the world) and the benefits of a multilateral system in terms of continued or improved access to germplasm of breeding programs is obvious.

72. The relevance of AAPG9 is fully applicable to AgBD but again fairly general. Do the benefits arising from participatory and multidisciplinary approaches really need to be stated? Principle 9 is thematically related to principle 2 and its emphasis on the empowerment of farmers. The participatory dimension of Principle 9 mostly concerns the primary stakeholders of AgBD, which are farmers (particularly in traditional agricultural systems), breeders and *ex situ* curators. This includes participatory plant breeding, linkages between on farm management of AgBD and *ex situ* conservation.

73. An illuminating and celebrated example of a participatory and multi-stakeholder approach to re-introduce sustainably native potato diversity into farming systems is the recent experience of the International Potato Center with the Tikapapa project. This project used the participatory marketing approach to involve all stakeholders of the potato value chain for concerted action and research to derive greater value from native potato diversity with clear benefits for farmers and greater diversity in potato fields.

74. Another example for participatory and multi-stakeholder approaches is the agroforestry project in Sub-Saharan Africa on the domestication of Allanbackia trees, involving farmer communities, ICRAF, the private sector and other stakeholders of this underutilized species.

75. Recent economic work of the CGIAR, FAO and others on the valuation of PGR and AnGR, fully addresses AAPG10 and confirms its applicability and relevance to AgBD. Principle 10 is also consistent with CBD decision VIII/25 on "Incentive measures: application of tools for valuation of biodiversity and biodiversity resources and functions". The economics of AgBD has several dimensions and there is a range of themes relevant to principle 10:

i. Developing valuation approaches and tools;

ii. Research on the cost and benefits of gene-banks/on-farm conservation;

iii. Payment for Agrobiodiversity Conservation Services;

iv. Modeling management costs of crop wild relatives in protected areas;

v. Market-driven approaches for the conservation of AgBD yielding highly differentiated products;

vi. Non-market values (socio-cultural and insurance functions, option values); and

vii. Policy development.

76. There are now many case studies involving a range of species, varieties and native products in several regions of the world that explore the use of market-based approaches to on-farm AgBD management and livelihood improvement. This approach is based on the premise that high-value commodity differentiation and increasing competitiveness in niche and novelty markets can provide incentives for the conservation of agricultural biodiversity. The cases illustrate the varying extent to which collective action, genetic variation, post-harvest quality management, site characteristics as well as innovative marketing add value to products derived from AgBD. They also show the potential trade-offs between income generation, livelihood security and conservation outcomes. A particularly instructive example is how, in recent years, the strongly growing market demand for highly differentiated fine-flavoured cocoa has stimulated investment in research designed to understand the value of cacao landraces in quality production and diversification.

77. Applied to AgBD, AAPG11 is similar to principle 5, in terms of avoiding or minimizing the effluents from agricultural areas, nitrogen leakage into water bodies, and pesticide contamination of soils. This principle applies to agriculture but not to the sustainable use of AgBD.

78. AAPG12 and its rationale are conceived in reference to local communities in the context of non-agricultural biodiversity, and principle 12 needs some re-interpretation for application to AgBD. As users of AgBD, indigenous communities by default derive considerable benefits from AgBD through the use and sale of agricultural products. However, there is general recognition of the need for indigenous and local communities to derive greater benefits from their custodianship of AgBD.

79. There are three ways farmers can be assisted to derive greater benefits from the AgBD they manage:

i. By materializing benefits through the enforcement of farmer rights or Intellectual Property Rights;

ii. By increasing the private (market) value of agricultural production, through improved marketing, value addition, high-value product differentiation (also dealt with under principle 10); and

iii. By compensating farmers for their conservation functions through Payment for Agrobiodiversity Conservation Services, a concept that is similar to payment for environmental services.

80. AAPG14 is highly relevant to AgBD, in view of AgBD's "orphan" status relative to non-agricultural biodiversity in the minds of environmental policy makers and the general public. Public awareness could help increase the disproportionately low share of investment going into the conservation of AgBD and enhance general appreciation for its importance to humans and the threats it faces. Principle 14 is stated more like an activity than as a principle. It is very similar in meaning to activities 3.5 and 4.3 of the programme of work on agricultural biodiversity, both of which aim at improved public awareness of the value, goods and services of AgBD. Both the rationale for the principle and the operational guidelines describe in fairly general terms process rather than content. For the principle to be of practical value, the associated guidelines should provide examples for universal and priority messages that should be conveyed via the public awareness activities. Tentatively, these could include:

i. Need for greater investment in AgBD as an insurance policy for the future (target: policy makers);

ii. Health and ecosystem benefits from a diet based on diverse AgBD sources (target: education at different levels, general public); and

iii. The relation between consumption patterns and sustainable use of ABD.

3.3. Comparing the AAPG with other normative frameworks concerning sustainable agriculture

81. Despite common perceptions to the contrary, agricultural science, policy making and practice has sought to reduce the negative environmental impact of agriculture, although arguably there is an implementation deficit. There are a considerable number of normative frameworks that prescribe sustainable production methods and principles for agriculture as a whole, or more commonly, for its sub-sectors.

82. Table 3 lists a select number of such principles and production guidelines. Notable are the comprehensive national or international frameworks for good agricultural practices or general principles of organic agriculture, which are conceived as normative frameworks for the certification of agricultural produce. Other principles deal in a more specific manner with particular sectors such as animal welfare, particular commodities (soybean, cocoa, oil palm), or refer to highly specific issues such as waste water management at the environment-agriculture-health interface. Others are concerned with the sustainable use of plant genetic resources, such as the global Plan of Action for Plant Genetic Resources for Food and Agriculture (GPA-PGRFA), an influential framework of principles that has guided national conservation policies and a number of international processes. Some of these frameworks are periodically reviewed to adjust to changing environmental challenges or emerging technologies (such as GMOs). For instance, the International Federation of Organic Agriculture Movements (IFOAM) meets periodically to review the standards and principles of organic agriculture. There is a huge body of agricultural and inter-disciplinary knowledge that has shaped these normative frameworks.

83. Table 3 also contains examples for sustainable agricultural practice guidelines that represent the growing number of normative frameworks by industry in response to widespread concerns about the sustainability of sourced raw materials such as cocoa, palm oil and soybean. Interestingly, industry principles (cocoa, palm oil) are structured to address the three "pillars" of the common sustainability definitions: environmental, economic and social. Unilever's guidelines on sustainable oilpalm production are particularly noteworthy, in terms of their specificity regarding the maintenance of soil fertility, crop and non-agricultural diversity, minimized fossil fuel use, water use for irrigation and processing, as well as workforce welfare. Being one of the largest buyers of palm oil, and explicitly recognizing the link between palm oil production and forest destruction, Unilever has pledged to source palm oil only from sustainable sources by 2015 [10].

10 http://www.unilever.com/sustainability/environment/agriculture/sustainablepalmoil/

84. Table 4 examines four normative frameworks of sustainable agriculture in greater detail and identifies their commonalities with the AAPGs. These frameworks are the aforementioned GPA-PGRFA, the Principles of Sustainable Biofuels, Good Agricultural Practices and European Regulation 834/2007, the recently revised harmonised framework for Organic Agriculture in EU member states. The table was constructed by going through these frameworks, and assigning their components -variably called “priority activities”, “principles” or “practices”- to thematically corresponding AAPGs.

85. A glance over Table 4 reveals that normative frameworks have more or less pronounced gaps, suggesting greater thematic breadth of the AAPGs. On the other hand, it proved difficult, if not impossible, to relate certain (important) elements of the normative frameworks of sustainable agriculture listed in Tables 3 and 4 to any of the 14 AAPGs (results not shown). Examples include the issues of animal welfare (an element of organic and good agricultural practices), public health and integrated food or value chain management. The latter are particularly prominent in principles concerned with particular commodities (soybean, cocoa, palm oil) since agricultural sustainability issues extend beyond the production or ecosystem level. Interestingly, the AAPGs put much emphasis on the rights of indigenous communities, perhaps as a reflection of the stakeholders involved in conceptualizing the AAPGs, whereas various frameworks of sustainable agriculture emphasize the rights and welfare of farm workers, a numerically important group, but of lesser political prominence.

Table 3: Selected examples of sustainability frameworks for specific agricultural sectors

Name of principles	**Main purpose of principles**	**Source**
Good Agricultural Practices Principles	Non-prescriptive guidelines for plant and animal production, human and animal welfare, and ecosystem health; serving as a technical reference for producers to develop locally appropriate good agricultural practice programmes.	FAO http://www.fao.org/prods/gap/home/principles_en.htm
IFOAM Principles of Organic Agriculture	The conceptual foundation of global organic agriculture, emphasizing health, ecology, fairness and care.	International Federation of Organic Agriculture Movements (IFOAM) http://www.ifoam.org/about_ifoam/principles/index.html.
EU regulation on organic agriculture (No 834/2007)	Recognizing that organic agriculture contributes to greater environmental sustainability, biodiversity and animal welfare, the regulation sets out comprehensive and detailed rules for organic production and the labeling of organic products that are binding across all EU member states.	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF
Principles of Sustainable Biofuels	Directed mainly to biofuel producers, with emphasis on ecological, economic and legal measures that are highly specific to ensure sustainability of biofuels in project planning.	Roundtable on Sustainable Biofuels (2007) http://cgse.epfl.ch/page65660-en.html.
Codex Alimentarius	Internationally recognized standards and recommended practices relating to the labelling, hygiene, additives and pesticide residues of food, and procedures for assessing the safety of foods derived from modern biotechnology. Also provides guidelines for the management of import and export inspection and certification systems for foods.	http//www.codexalimentarius.net
Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)	Adopted in 1996 by representatives of 150 countries, the GPA-PGRFA provides a strategy for international cooperation to conserve and sustainably use PGRFA and ensure the fair and equitable benefit-sharing arising from the use. The GPA's succinctly stated aims and principles refer to in situ conservation, on-farm management, restoration of agricultural systems after disasters, ex situ conservation, enhanced use of PGRFA in markets, seed systems and agricultural systems.	http://www.fao.org/ag/AGP/AGPS/Pgrfa/pdf/gpaeng.pdf
Global Plan of Action for Animal Genetic Resources (FAO, 2007)	Based on an authoritative assessment of global livestock biodiversity in 169 countries, the GPA-AnGR is an internationally agreed framework to halt the erosion of livestock diversity and support the sustainable use of animal genetic resources. It outlines a series of strategic priorities for the conservation, inventorying and development of AnGR.	http://www.fao.org/docrep/010/a1404e/a1404e00.htm
Guidelines on Best Known Practices in the Cocoa Value Chain	Principles agreed by the *Round Table on a Sustainable World Cocoa Economy*, an alliance of cocoa farmers, co-operatives, traders, exporters, warehouse keepers, processors, manufacturers, governmental and non-governmental	http://www.roundtablecocoa.org

Name of principles	Main purpose of principles	Source
	organizations, financial institutions and donor agencies from 25 countries, spanning the five continents of the world.	
Sustainable Palm Oil Good Agricultural Practice Guidelines	Voluntary private sector guidelines (Unilever 2003), providing guidance on sustainable management practices for oil palm plantation with highly specific recommendations regarding the maintenance of soil fertility, crop and non-agricultural diversity, product quality, minimized fossil fuel use, water use for irrigation and processing, as well as workforce welfare.	http://unilever.com/images/SustainablepalmoilGoodAgriculturalPracticeGuidelines2003_tcm13-5316.pdf
Principles and Criteria for Responsible Soy	Espouses the principles of 1) legal compliance 2) responsible labor conditions, 3) community relations, 4) environmental responsibility, and 5) Good Agricultural Practice; draft released for field testing in 2009 by Round Table on Responsible Soy Association (RTRS), an association of producers, CSOs and companies to "facilitate a global dialogue on soy that is economically viable, socially equitable and environmentally sound".	http://www.responsiblesoy.org/principles_criteria_docs.php
Guidelines for the safe use of wastewater, excreta and greywater	WHO guidelines with emphasis on use of wastewater in agriculture, including very detailed best practices covering aspects of regulation, health, environment, contaminants, irrigation, fertilization purposes, sociocultural factors.	http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html
Guidelines for Providing Native Bee Habitat on Farms	A guide to protect and enhance habitat for native crop pollinators in the farm landscape, including advice on simple changes that can be made in farm management for the benefit of native bees, as well as information on how to enhance or provide important habitat features, such as nest sites and forage.	http://www.xerces.org

86. Closer examination of particular rows in Table 4 shows that normative frameworks of sustainable agriculture offer a much higher level of specificity than corresponding AAPGs. Where AAP11 demands “avoidance and minimization of waste”, FAO’s Good Agricultural Practices address *inter alia* the problem of nitrate run-off and greenhouse gas emissions from farm animals. EU Regulation 834/2007 is even more specific in terms of identifying permitted farm inputs that minimize avoidance of waste and “adverse impacts on ecosystem services” (AAP5). The Principles of Sustainable Biofuels provide a succinct overview on the concrete measures to make biofuel projects less harmful to the environment. Here, science-based recommendations for a particular agricultural sector can be found, typically agreed on by representative groups of stakeholders, whereas corresponding AAPGs need considerable interpretation to tease out their intended meaning and applicability to agriculture and agricultural biodiversity.

87. The greater thematic specificity of the agricultural sustainability principles in Table 4 *vis-à-vis* the AAPGs would suggest they target different audiences. Indeed, these can be policy makers, farmers, oil palm growers, etc.

88. Finally, in none of the frameworks of sustainable agriculture inspected more closely for the present information note (those in Table 3) were references to the AAPGs found. This is not to say that the AAPGs are not relevant to agriculture, but clearly they have not been used in shaping or inspiring the thinking about sustainable agriculture, a conclusion consistent with the absence of AAPGs from country reports and voluntary reports (see previous section). The CBD fourth national reports generally do not offer much information on agricultural biodiversity either and they are largely silent on the AAPG, as compared with the more specific information and case studies on sustainable use contained in FAO’s State of the World Reports, presumably because CBD focal points represent mostly environmental ministries and are not the same as FAO’s contact points.

89. The analysis in the preceding sections confirms that the AAPGs are a valid general framework for the sustainable use of biodiversity and sustainable agriculture with important messages targeted to a global audience. They are broadly applicable to agriculture in general and to a lesser extent to the sustainable use of agricultural biodiversity in particular (as defined under 2.4.). However, they are stated in very general terms, and their wording and the accompanying rationales reflect concerns about the sustainability of use of non-agricultural biodiversity. In order for the AAPGs to be of operational value in agriculture and provide meaningful guidance for improved management they would need considerable re-interpretation (see also Rischkowsky 2008).

90. It is suggested that existing normative agricultural frameworks aimed at greater sustainability as presented and discussed in the previous section be “marketed” and used to a larger extent. As compared with the AAPGs, these frameworks offer more specificity in terms of thematic focus and target audiences, and greater potential to guide priority action suited to particular circumstances of the highly diverse agricultural systems. These frameworks also represent good models for the development of production principles or standards for agricultural sub-sectors for which such principles do not yet exist.

Table 4: Equivalence and specificity of action principles aimed at sustainable agriculture as compared with the AAPG

Addis Ababa Principles (AAP)	**Priority Activities (PA) of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)**	**Principles of Sustainable Biofuels (PSB) (2007)** [b]	**Good Agricultural Practices Principles (FAO, 2003)** [c]	**European Regulation on organic agriculture (No 834/2007)** [c]
AAP1: Supportive policies, laws and institutions are in place at all levels and there are effective linkages.	PA15: Building strong national programmes. PA16: Promoting networks for PGRFA.	PSB1: Biofuel production to be consistent with national applicable laws as well as with obligations acquired through international treaties relevant to biofuels' production.	Harvesting must conform to regulations relating to pre-harvest intervals for agrochemicals and withholding periods for veterinary medicines.	Regulation 834/2007 seeks to harmonize national and private label certifications of organic agriculture, thus providing a coherent framework across EU member states. Regulation is also concerned with consumer health, the agricultural value chain incl. processing.
AAP2: Local users of biodiversity should be empowered by rights to be accountable for use of the resources.		PSB 4: Biofuel production shall not violate human rights or labor rights, and shall ensure decent work and the well-being of workers. 4a: freedom of association; 4b, c: no slave, forced or child labor; 4e, f: working conditions respect applicable law and international conventions.		Art. 27 sets out detailed rules for the functioning of a control system to make farmers accountable for the use of organic production standards.
AAP3: Policies that distort markets or represent perverse incentives for degradation should me removed or mitigated.		PSB11.a: Biofuel projects should seek to be economically viable without distortive public support (for instance, tariffs and subsidies).		
AAP4: Adaptive management through science, traditional knowledge, and feedback from use and impact assessment.	PA1: Surveying and inventorying plant genetic resources for food and agriculture. PA2: Supporting on-farm management and improvement of PGRFA. PA3: Assisting farmers in disaster situations to restore	PSB11.e: The use of genetically modified: organisms for biofuel production must improve productivity and maintain or improve social and environmental performance, as compared to common practices and materials under local conditions. PSB11.f: Micro-organisms used in biofuel processing must be used in contained systems only.	Minimize non-therapeutic use of antibiotics or hormones in farm animals; Avoid crops with high water requirements in a low availability region; Avoid feeding animals with animal wastes or animal matter (reducing the risk of alien viral or transgenic genes, or prions such as mad cow disease); Minimize transport of live animals (by foot, rail or road) (reducing the risk of epidemics, e.g., foot and mouth	Organic agriculture borrows heavily from traditional agriculture and integrates traditional knowledge (crop rotation, integration of animal husbandry and field cropping) with scientific insights in nutrient and disease management.

Addis Ababa Principles (AAP)	**Priority Activities (PA) of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)**	**Principles of Sustainable Biofuels (PSB) (2007) [b]**	**Good Agricultural Practices Principles (FAO, 2003) [c]**	**European Regulation on organic agriculture (No 834/2007) [c]**
	agricultural systems. PA5 & PA6: Sustaining existing, and regenerating threatened, ex situ collections.		disease); Apply traceability processes on the whole production chain (breeding, feed, medical treatment.) for consumer security	
AAP5: Avoidance of adverse impacts on ecosystem services and components.	PA11: Promoting sustainable agriculture through diversification of crop production and broader diversity in crops.	PSB3: Biofuels shall contribute to climate change mitigation by significantly reducing GHG emissions as compared to fossil fuels. PSB7.a: High Conservation Value areas, native ecosystems, ecological corridors and other public and private biological conservation areas shall be identified and protected.	Optimize fertilizer application to avoid run-off; Avoid soil compactation; Prevent erosion through hedging and ditching; minimize the impact of operations such as tillage and agrochemical use on wildlife; manage field margins to reduce noxious weeds and to encourage a diverse flora and fauna with beneficial species; manage water courses and wetlands to encourage wildlife;	Conservation tillage; ban on mineral nitrogen fertilizers; pest and disease control through natural enemies, crop rotation, cultivation techniques, choice of resistant varieties; use of wild species should not affect the stability of the natural habitat or the maintenance of the species (Art. 12). Husbandry practices shall minimise negative environmental impact from the holding, including the escape of farmed stock (Art. 15).
AAP6: Support of interdisciplinary research into all aspects of use and conservation of biological diversity.	PA9 & PA17: Expanding the characterization and evaluation of core collections to facilitate use, and constructing comprehensive information systems for PGRFA. PA17: Constructing comprehensive information systems for plant genetic resources for food and agriculture. PA14: Developing new markets for local varieties and "diversity-rich" products.			n.a.
AAP7: Spatial and temporal scales of management should be				

Addis Ababa Principles (AAP)	Priority Activities (PA) of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)	Principles of Sustainable Biofuels (PSB) (2007) [b]	Good Agricultural Practices Principles (FAO, 2003) [c]	European Regulation on organic agriculture (No 834/2007) [c]
compatible with the ecological and socio-economic scales of the use and its impact.				
AAP8: International arrangements for international cooperation where multi-national decision-making are needed.				The rationale for regulation 834/2007 was originally to provide EU-wide common principles for organic production. Art. 32 & 33 provide detailed guidelines for trade of organic or equivalent products with third countries.
AAP9: Interdisciplinary, participatory approach for management and governance related to the use.		PSB2: Biofuels projects shall be operated under appropriate, transparent, consultative, and participatory processes that involve all relevant stakeholders.	In relation to holistic crop protection, use resistant cultivars and varieties, crop sequences, associations, and cultural practices that maximize biological prevention of pests and diseases;	
AAP10: Policies need to take into account use and non-economic values of biodiversity and market forces affecting the values and use.	PA11: Promoting sustainable agriculture through diversification of crop production and broader diversity in crops. PA12. Promoting development and commercialization of under-utilized crops and species.			
AAP11: Avoidance or minimization of waste and optimized benefits from uses.		PSB6.a: Biofuel production shall minimize negative impacts on food security by giving particular preference to waste and residues as input (once economically viable), to degraded/marginal/underutilized lands as sources, and to yield improvements that maintain existing	Prevent waste run-off (e.g. nitrate contamination of water tables from pigs), nutrient loss and greenhouse gas emissions (methane from cows); Maintain permanent soil covering, in particular in winter to avoid nitrogen run-of;	To avoid environmental pollution, in particular of soil and water, organic production of livestock should provide for a close relationship between such production and the land, suitable multiannual rotation systems and the feeding of livestock with organic-farming crop products

Addis Ababa Principles (AAP)	Priority Activities (PA) of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)	Principles of Sustainable Biofuels (PSB) (2007) [b]	Good Agricultural Practices Principles (FAO, 2003) [c]	European Regulation on organic agriculture (No 834/2007) [c]
		food supplies. PSB8c: Wastes and byproducts from processing units shall be managed such that soil health is not damaged. PSB10.b: Open-air burning shall be avoided in biofuel production.		produced on the holding itself or on neighbouring organic holdings. Use of non-toxic inputs in production and processing.
AAP12: Local custodians of biological diversity need to benefit from the uses of these resources.		PSB5: Biofuel production shall contribute to the social and economic development of local, rural and indigenous peoples and communities. PSB12.b: Local people shall be fairly compensated for any agreed land acquisitions and relinquishments of rights under free prior and informed consent.		Although not explicit about local custodians of biological diversity, organic agriculture de facto helps preserve old crop landraces and rare breeds.
AAP13. The costs of management and conservation of biological diversity should be internalized within the area of management and reflected in the distribution of the benefits from the use.				
AAP14. Implementation of education and public awareness programmes on conservation and sustainable use; more effective communication between stakeholders	PA20. Promoting public awareness of the value of PGRFA.	PSB5.b: Special measures that benefit women, youth, indigenous communities and the vulnerable in the affected and interested communities shall be designed and implemented, where applicable.		Art. 23 & 24 spell out labelling requirements for organic products as an important communication strategy directed at consumers. Equally important is the use of authorized organic production logos (Art. 25).

Addis Ababa Principles (AAP)	Priority Activities (PA) of the Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 1996)	Principles of Sustainable Biofuels (PSB) (2007) [b]	Good Agricultural Practices Principles (FAO, 2003) [c]	European Regulation on organic agriculture (No 834/2007) [c]
and managers.				

[a] Principles re-worded for brevity

[b] Principles of Sustainable Biofuels have very specific “sub-principles” of which only a selection can be shown here for limitations of space

[c] Principles reproduced in the table represent only a minor fraction of these very comprehensive and specific frameworks

91. While the principles we have reviewed may reflect the bias or the special interests of particular agricultural sectors, it is futile to argue about the "orthodoxy" of the "correct" sustainability approach. In section 2.3 the argument was presented that whilst agricultural sustainability needs to be achieved at a global level, there might be trade-offs at different spatial or temporal scales, in terms of negative agricultural externalities being compensated for improvements in other areas or times. In achieving global sustainability there might even be a need for trade-offs between the agricultural and non-agricultural sectors (carbon trading?). In combination with the complexities of agricultural systems, such trade-offs make it even more unlikely that any particular set of general principles will have much operational value. Rather, it is reasonable to assume that the large number of existing agricultural normative frameworks, if more widely applied, would move agriculture toward a more sustainable future.

92. In essence, it is concluded that, in the field of agriculture, the AAPGs offer no real added value over existing and more relevant conceptual frameworks other than re-affirming them. These other frameworks are fully compatible with the CBD. Agriculture has no shortage of sustainability principles and guidelines, but judging from its environmental footprint, certainly lacks their implementation.

4. TOWARD A MORE SUSTAINABLE AGRICULTURE

4.1. The need for sustainable intensification

4.1.1. Increased demands on agriculture

93. The human population is expected to grow to over 8 billion people by the year 2030, and is likely to plateau at some 9 billion people by 2050 (Cohen 2003, UN 2004). These figures are considered the most likely population scenario. Every day the total human population increases by over 200,000 people[11]. The highest percentage increase over the next 20 years is expected in sub-Saharan Africa (80%).

94. An annual increase of 1.3% in food production is necessary at the present time to feed the burgeoning human population, assuming present diets remain the same. However, wealthier populations consume more animal products, and a doubling of cereal yields may be necessary by 2050 (Smil 2000, Land Commodities 2009, Godfray 2010). This doubling will result from a projected 2.4-fold increase in per capita real income and from dietary shifts toward a higher proportion of meat (much of which is grain-fed) associated with higher income (Tilman et al. 2002).

95. Although the annual growth rate for animal products has somewhat slowed recently, global production of meat is projected to more than double from 299 million tonnes in 1999/2001 to 465 million tonnes in 2050, and that of milk to increase from 580 to 1043 million tonnes. The bulk of the growth in meat and in milk will occur in developing countries (FAO 2006, quoted in Steinfeld *et al.* 2006).

96. By 2030, 60% of the world's population will be living in urban areas, and by 2050 this proportion is projected to rise to almost 70%[12]. Cropland and population are not uniformly distributed (for example, China has 7% of the world's arable land and 20%-25% of the world's population). Enormous challenges lie ahead to ensure the production and distribution of food products.

97. Approximately 120 countries are net importers of food grain (Goklany 1999). Based on current trends, most developing countries will have to lean heavily on imported food as they do now. Required rises in crop yields will not come about without policies that attach high priority to agricultural research

11 UN Population Division (2007). UN 2006 population revision. UN, New York. http://esa.un.org/unpp/

12 United Nation Population Division, http://esa.un.org/unup

(Alexandratos, 2000; Johnson, 2000). Worldwide funding for agricultural research, however, has declined substantially in the last 20 years. These problems are exacerbated by diminishing cropland area due to erosion; fewer non-renewable resources, such as potassium and phosphate; less of, and consequently more expensive, water; and a reduced population working the land (Kishore and Shewmaker, 2000).

4.1.2. Limited potential for area expansion of cultivated lands

98. Historically, the primary solution to food shortages has been to bring more land and water into agriculture. Yet over the past five decades, while grain production has more than doubled, the amount of land devoted to arable agriculture globally has increased by only ~9% (Pretty 2008). The best land is almost certainly in agricultural production; what is left is usually of poor quality and likely to produce poor yields (Tilman *et al.* 2002). The Comprehensive Assessment of Water Management in Agriculture (IWMI 2007) has concluded that scope for irrigation expansion is now limited and the major opportunities lie in enhanced rainfed agriculture and improvements in water use efficiency.

99. Some new land could be brought into cultivation, but the competition for land from other human activities makes this an increasingly unlikely and costly solution, particularly if protecting biodiversity and the public goods provided by natural ecosystems (for example, carbon storage in rainforests) are given higher priority.

100. In recent decades, agricultural land that was formerly productive has been lost to urbanization and other human uses, as well as to desertification, salinization, soil erosion, and other consequences of unsustainable land management (Nellemann *et al.* 2009). Recent policy decisions to produce first-generation biofuels on good quality agricultural land have added to the competitive pressures. Thus, the most likely scenario is that more food will need to be produced from the same amount of, or even less, land. Indeed, for the last three consecutive years the record shows that total global agricultural land area (and the arable subcomponent) has actually diminished[13].

101. In countries with high levels of productivity and low population growth rates, the extent and distribution of land under cultivation is stabilizing or even contracting (for example, Australia, Japan, the United States, and Italy). The area in agricultural production has also stabilized and begun to contract in China. But some countries, predominantly found in sub-Saharan Africa, have had persistently low levels of productivity and continue to rely mainly on the expansion of cultivated area, a process that is increasingly becoming unsustainable (MEA 2005).

4.1.3. The need for agricultural intensification

102. The combination of increasing demand for agricultural production and limited potential for the expansion of cultivated lands leave no alternative but to further improve the productivity of existing agricultural lands, in a rather dramatic fashion (Fresco 2007). Seemingly a paradox, it is the intensification of agriculture, probably even to a large extent in diversity-poor systems that will relieve the pressure on natural systems and contribute to the conservation of non-agricultural biodiversity. In other words, the greatest potential to safeguard biodiversity lies in good agricultural practice and new cropping and livestock systems in order to intensify agriculture and reduce the pressures on natural ecosystems. This is especially relevant in the vast but currently rather unproductive rural areas in the developing world, in order to avoid further nature and habitat loss due to expansion of agricultural land (Fresco 2007). Avery (1999) contends that recourse to less efficient forms of agriculture, for supposed environmental reasons, will result in plowing up of yet more wilderness and cutting down forest to feed the increasing population.

13 FAOSTAT (2009). FAOSTAT. http://faostat.fao.org/default.aspx

103. The primary need, therefore, is not to avoid intensification but to actively support it but ensuring that intensification be sustainable. Intensification of production to gain more output per unit land area and time runs the risk of unintended negative impacts associated with greater use of external inputs such as water, fuel, irrigation, fertilizer, and pesticides. Therefore, the only real option for improving yields is a process of sustainable intensification, with due regard to the lessons learnt from irrational and poor use of agrochemicals and water in the past.

104. Sustainable intensification is defined as an increase in the efficiency of the use of land, water, fertilizers and pesticides, while avoiding environmental degradation (Godfray 2010). This boils down to what has been called a second Green Revolution, boosting land, water and labour productivity and enabling greater diversification of diets and income generation in rural areas (Tilman *et al*. 2002, Trewavas 2001, 2002). The extent to which crop yields can be raised is considerable, in particular in poor countries. For example, average cassava yields in many parts of the tropics are less than 10 tonnes wet weight per hectare (t/ha), compared to 50 t/ha at the best farms in Nigeria and 100 t/ha at the best farms in Brazil (Fresco 2007). It has been estimated that in those parts of Southeast Asia where irrigation is available, average maximum climate-adjusted rice yields are 8.5 metric tons per hectare, yet the average actually achieved yields are 60% of this figure (Cassman 1999). Similar yield gaps are found in rain-fed wheat in central Asia and rain-fed cereals in Argentina and Brazil. Substantially more food, as well as the income to purchase food, could be produced with current crops and livestock if methods were found to close the yield gaps (Godfray et al. 2010).

105. Low yields occur because of technical constraints that prevent local food producers from increasing productivity or for economic reasons arising from market conditions. For example, farmers may not have access to the technical knowledge and skills required to increase production, the finances required to invest in higher production, or suitable crop and livestock varieties. After harvest or slaughter, they may not be able to store the produce or have access to the infrastructure to transport the produce to consumer markets. Farmers may also choose not to invest in improving agricultural productivity because the returns do not compare well with other uses of capital and labour. Exactly how best to facilitate increased food production is highly site-specific (Godfray 2010).

106. Powerful support for the need of agricultural intensification comes also from a study of Wise *et al.* (2009) who modelled carbon emissions from land use and industrial sources under different regimes of carbon taxation and limiting atmospheric CO_2 concentrations. They found that in a scenario of “frozen agricultural productivity” at 2005 levels, crop land expansion dramatically encroaches on forested lands, releasing the carbon stored in forest vegetation and soils. They conclude that improved crop productivity has the potential to reduce anthropogenic carbon emissions at a magnitude similar to improved energy technologies.

107. A case where the need for intensification is particularly obvious is the low intensity cacao systems in the humid forest of West Africa, where sustainable intensification of the crop is urgently required to avoid the destruction of what has remained of the Guinea Forests (Gockowski & Sonwa 2008).

108. Sustainable intensification will also apply to “industrial” forms of agriculture, which have enabled current trends in consumption and urbanization. For example, almost the entire expansion in output from poultry and pigs, globally, and from beef and milk cattle in industrial countries, has taken place in intensive, industrial production systems (MEA 2005). This has provided food in relatively safe, reliable, and progressively cheaper ways, but there have been many examples in both industrial and developing countries of a wide range of soil, water, and odour pollution problems, as well as potential large-scale health risks from the more intensive production of livestock (Otte *et al.* 2007). Large-scale facilities are economically competitive because of production efficiencies, but their health and environmental costs must be better quantified to assess their potential role in sustainable agriculture (Tilman *et al*. 2002). However, it is not the industrial livestock system itself that is necessarily

unsustainable but rather how it is managed. According to Weary *et al*. (2008) environmental degradation from livestock systems occur at both the high and low end of the intensity spectrum. Interestingly, the environmental problems created by industrial livestock systems do not derive from their large scale – apart from extreme cases – or production intensity, but from their geographical location and concentration preventing sustainable waste management (Weary *et al*. 2008). Environmental concerns need to shape the distribution of livestock production in addition to considerations of access to input and output markets (Steinfeld 2006).

4.2. Reducing agriculture's environmental impact

4.2.1 Nutrient flows

109. Intensification of food production involving increased use of fertilizers adds globally significant and environmentally detrimental amounts of nitrogen and phosphorus to terrestrial ecosystems, at rates that may triple if past fertilization and crop management practices are used to achieve another doubling in food production (Cassman & Pingali 1995). Increased fluxes of plant nutrients to agricultural systems under current practices lead to imbalances and emissions to aquatic ecosystems. While other nutrients are also important, their use in agriculture and their effects on global ecosystem services are much smaller. Hence, this section will focus on nitrogen and phosphorus.

110. Figures concerning the extent to which agriculture and other human activities are contributing to nitrogen and phosphorus pollution vary greatly. They largely depend on the intensity of agriculture, particularly on the size and concentration of cattle feed lots at the coasts and within the catchment basins of rivers discharging to the sea or ocean, as well as on the intensity of urbanization and industrialization[14].

111. Eutrophication and oxygen depletion caused by nitrogen and phosphate leaching from agricultural lands has resulted from the profligate use of manures and fertilizers (Smil 1997). The fact that the livestock sector is industrializing, in a number of concentrated locations, separates the sector from its supporting land base and interrupts the nutrient flows between land and livestock, creating problems of depletion at the source (land vegetation and soil) and problems of pollution at the sink (animal wastes, increasingly disposed of into waterways instead of back on the land) (Weary *et al*. 2008).

112. The impacts of N and P use in agriculture on inland water ecosystems, including groundwater quality, and subsequent impacts on coastal ecosystems is reviewed further in document UNEP/CBD/SBSTTA/14/INF/3.

113. In pre-industrial times, the annual flux of nitrogen from the atmosphere to the land and aquatic ecosystems was 90–130 million tons per year. This was more or less balanced by a reverse ‘‘denitrification’’ flux. Use of synthetic nitrogen fertilizer, expanded planting of nitrogen-fixing crops, and the deposition of nitrogen-containing air pollutants have together created an additional flux of about 200 million tons a year, only part of which is denitrified. The increased nitrogen use has permitted a large increase in food production, but at the cost of increased emissions of greenhouse gases and a frequent deterioration in freshwater and coastal ecosystem services, including water quality, fisheries, and amenity value (MEA 2005).

114. Nitrogen losses or fluxes are in the form of nitrate, ammonia or nitrous oxide. Nitrate, which is very mobile in the soil solution, when not taken up by the growing plants, may be leached to the ground water or enter a subsurface flow. Through this it may enter streams and rivers. Nitrogen is also lost through volatilisation/evaporation of ammonia. Such losses are mainly originating from animal excreta.

14 http://www.fao.org/gpa/nutrients/econ.htm

Further nitrogen losses occur in form of nitrous oxide. High nitrogen losses occur especially on sandy, permeable soils[15].

115. In contrast to the rather mobile nitrate, soil phosphorus is quite immobile. Hence, under normal conditions the topsoil (ploughing layer) will be the richest in phosphorus. Erosion can therefore result in great particulate losses of phosphorus to surface waters (Smith et al. 1996, Hodgkin and Yeates 1993) (run-off), especially just after manure or fertilizer application and when phosphorus in form of animal manure or mineral fertilizer is spread on the surface of permanent grassland or no-till-systems. It may then be dissolved by rain in surface water and be washed into water systems (Cullen 1974).

116. Phosphorus is accumulating in ecosystems at a rate of 10.5–15.5 million tons per year, mainly as a result of the use of mined phosphorus in agriculture, which compares with the pre-industrial rate of 1–6 million tons of phosphorus a year. Most of this accumulation is occurring in soils, which may then be eroded into freshwater systems, causing deterioration of ecosystem services. This tendency is likely to spread and worsen over the next decades, since large amounts of P have accumulated on land and their transport to water systems is slow and difficult to prevent.

117. In spite of its immobility leaching of phosphorus (P) may become a problem only under special soil conditions and on soils highly saturated with phosphorus (P) (Harris *et al*. 1994). This may be the case where extensive amounts of animal manure or slurry from feed lots have been applied on a surface which is proportionally too small.

118. A clear distinction must be made, however, between the overuse or inefficient use of nitrogen and phosphorus in parts of the world and the desperate need for substantial increases in the amount of these nutrients applied to crops in regions like sub-Saharan Africa where yields are low and often declining—because soil nutrients taken off agricultural land as harvested products are not sufficiently replenished (also called soil mining). In regions where phosphorus fertilizers are not available or affordable, agricultural productivity can be severely limited (MEA 2005).

4.2.1.1 Options to sustainably increasing fertility of impoverished soils.

119. Many regions of the world, particularly Africa, are in urgent need of greater nutrient inputs to support food production. The proper use of these increased nutrients would not only increase the regional food supplies but would also improve soil characteristics and, therefore, lead to less soil loss from erosion. The challenge is how to ensure that nutrient replenishment in developing countries does not follow the pattern of excessive nutrient applications that now threatens many ecosystems. The best strategy for nutrient replenishments will depend on the soil, climate, agroecosystem, socioeconomic conditions, and policy environment. Most of these nutrient replenishment strategies entail a combination of mineral and organic inputs, with the exact mix determined in part by socioeconomic conditions as well as the realization that organic materials cannot, in general, supply sufficient P to meet crop demand (Palm *et al.* 1997).

120. Soil phosphorus can be replenished by application of soluble P fertilizers or reactive phosphate rock (RP) or a combination of both (Buresh *et al.* 1997). The direct application of phosphate rock is often proposed as the better alternative because of lower production costs than for soluble P fertilizers (Buresh *et al*. 1997). Phosphate rock deposits are found throughout Africa but they vary in their effectiveness for direct application to the soil (Mokwunye and Bationo 2002). The choice of P fertilizer depends on the soil, the climate, plant species, and the comparative costs. While organic inputs do not have sufficiently high concentrations of P to replenish soil P at reasonable application rates, they can increase soil P availability above that obtained through the same application rates of mineral P. High rates of P application are likely to have negative environmental effects, primarily through erosion and runoff.

15 http://www.fao.org/gpa/nutrients/econ.htm

Introduction of biological filter strips or biological terraces have proven quite effective in practically eliminating runoff and soil erosion of P; in addition, application of P increases the vegetative cover, practically eliminating runoff and loss of P by erosion.

121. Biological N fixation offers an economically attractive alternative to synthetic N fertilizers (Bohlool *et al.* 1992; Döbereiner et al. 1995). Intercropping and rotation cropping is commonly done with N-fixing legumes. In Cuba, large-scale production and use of Azotobacter (free-living, N-fixing bacteria) is estimated to supply more than half of the N needed by non-legumes (Oppenheim 2001). Brazil has become the world leader in replacing chemical fertilizers with biological N fixation, The mean value of N application is as low as 10 kilogram per hectare (Döbereiner 1997).

4.2.1.2 Options for improved nutrient management.

122. Much can be gained simply by eliminating excess N fertilizer. Adding more N increases crop yield only up to a point, after which the crop's need for N is saturated and further fertilization has no effect on production (NRC 2000). However, underestimation of N available from other sources, such as residues from previous crops, and particularly the relatively low cost of N fertilizers causes farmers in rich countries to apply significantly more synthetic N fertilizer than recommended, as ‘‘insurance’’ to guarantee maximal yield. Reducing fertilizer use by 20–30% would not affect yields, and in all likelihood, reduce the downstream N pollution by considerably more than 20–30%. Crop production insurances have been proposed to provide incentives for farmers to realize the potential savings of optimized fertilizer use (MEA 2005).

123. Particularly promising approaches for reducing N leaching from agricultural fields include growing perennial crops such as alfalfa or grasses rather than annuals such as corn and soybeans. Perennials retain N in the rooting zone and greatly reduce losses to groundwater. Another option is planting winter cover crops, which greatly reduce the leaching of nitrate into groundwater during winter and spring, when most leaching normally occurs. Also, applying N fertilizer at the time of crop need, rather than at the time of convenience or reduced labour peaks would help avoid much of the applied fertilizer being leached into the groundwater (Staver and Brinsfield 1998, Randall and Mulla 2001).

124. Another promising approach for reducing N (and other nutrient) losses is the use of precision agriculture, where the timing and amount of fertilization are closely matched to crop needs at relatively small spatial scales. Other benefits of precision agriculture include reduced amounts of applied pesticides and reductions in pesticide resistance development (Bongiovanni & Lowenberg-Deboer 2004). Also, genetic engineering may hold promise for increasing the nutrient use efficiency of crops (Wang *et al.* 2010).

125. The need for more efficient nutrient use is particularly urgent in the case of phosphorus, because the known reserves of economically available phosphate rock –which happen to be highly concentrated with 90% reported from only five countries– are predicted to be depleted in the next 50-100 years, mainly because of phosphate use in agriculture, an issue receiving insufficient attention in sustainability discussions (Cordell *et al*. 2009). Phosphorus scarcity needs to be placed on the priority agenda for global food security, as advocated by the Global Phosphorus Research Initiative[16].

126. Millions of tons of P contained in human excreta are currently lost as treated or untreated effluent discharged to rivers and oceans. This causes considerable pollution of inland water and coastal ecosystems. Improved wastewater management, by for example using suitably treated human wastes to fertilise fields, can help not only to relieve this stress on freshwaters but also redirect valuable phosphorous to sustainable agricultural purposes (see document UNEP/CBD/SBSTTA/14/INF/3 for further information). The most promising options for sustainable phosphorus use and management is such

16 http://phosphorusfutures.net/

recovery and use of human excreta for agricultural use, in particular of urine, which contains approximately 50% of the phosphorus (and 70% of the nitrogen and 50% potassium) in household sewage (Jönsson 2001). The feasibility of urine recovery has been shown in a pilot project in Tamilnadu, India, where the users of a community ecological sanitation toilet are paid, recognising the fertilizer value of their urine and faeces (http://www.ecosanres.org/pongalgift.htm).

4.2.1.3 Options for improved management of animal manure

127. Manure can, of course, be used as fertilizer, and recycling it back to agricultural fields has been practiced since the advent of agriculture. However, the geographic concentration of feedlots and distance from the agricultural land supplying feed make it expensive for the farmers to return the bulky animal wastes to the site of the original feed production. Instead it is far cheaper for farmers to purchase synthetic fertilizers to use on their fields (NRC 2000; Howarth *et al*. 2002). It is also difficult to apply manure at the time and rate needed by the crop, especially in high-intensity systems, due to the uncertainty about the time of nutrient release and the difficulty of spreading it uniformly.

128. Animal wastes can be composted to make them easier for use as effective fertilizers. However, much ammonia is volatilized to the atmosphere during the composting, which lowers the value of the compost as fertilizer and contributes to pollution by atmospheric deposition. More effective and less polluting methods for treating animal wastes are urgently needed (NRC 2000). Using pig waste as an example, Leneman *et al*. (1993) showed that a combination of measures of improved animal husbandry and crop management can result in dramatic reductions of N and P emissions. These included reducing N and P excretion by changes in feeding regime of the pigs, reduced N volatilization in improved manure storage structures, and reduced N and P leaching in the soil.

129. This section cannot do justice to the huge complexity of nutrient flows and improved agricultural soil management (such as reduced tillage and conservation agriculture), but it illustrates major issues. It shows that a more sustainable agricultural nutrient management is highly contextual and may warrant widely differing, even contrasting, practices. In those regions where soils are depleted, increased fertilizer use may be an important element of sustainability strategies, and even warrant subsidies to get fertilizers where they are most needed. In countries, where fertilizers prices do not account for negative externalities of profligate use, incentives to reduce this input may be needed to provide for greater environmental stewardship of farming.

4.2.2. Water use

130. Agriculture is by far the most consumptive human use of fresh water. Agriculture both relies on and influences the provision of fresh water. Water requirements for cultivation are large; it takes 500 litres, 1,400 litres, and 2,000 litres of transpired water to produce 1 kilogram of potatoes, maize, and rice, respectively (Klohn and Appelgren 1998). Whereas a person requires only 2–5 litres of water for drinking, producing the food to satisfy a person's daily dietary needs takes about 3,000 litres of water—about 1 litre per calorie (IWMI 2007).

131. About 80% of agricultural evapotranspiration—when crops turn water into vapour —comes directly from rain, and about 20% from irrigation (IWMI 2007). Of the 9,000–12,500 cubic kilometres of surface water estimated to be available globally for use each year (Shiklomanov 1996), total withdrawals are estimated at 3,800 cubic kilometres, with 2,700 cubic kilometres (or 70%) for irrigation, with huge variations across and within countries. Industrial and domestic use is growing relative to that for agriculture (Postel 1993, IWMI 2007).

132. Arid areas like the Middle East, Central Asia, tend to rely on irrigation. There has also been large-scale irrigation development in South and East Asia, less in Latin America, and very little in Sub-Saharan Africa. By 2002, there were 276 million hectares of irrigated cropland globally—five times more than at

the beginning of the twentieth century. While this irrigated area represents only 18% of all croplands, irrigated agriculture provides about 40% of the global food supply (Bruinsma 2003, IWMI 2007).

4.2.2.1 Increasing water use efficiency.

133. Irrigation systems are often inefficient in terms of water loss through evaporation and leakage. Global estimates of irrigation efficiency - defined as the ratio of water used by crops to the gross quantity of water extracted for irrigation use- vary, but the average is around 43% (Postel 1993). Seckler *et al*. (1998) estimate that arid agroecosystems have more efficient irrigation—for example, 54% and 58% efficiency for the two driest groups of countries, compared with 30% for the least water-constrained countries. China and India show irrigation efficiencies of around 40%, and they strongly influence the global average because of their large irrigated area.

134. In light of the observed water use inefficiencies, it is of great importance for agriculture to increase the productivity of water. Gaining more yield and value from less water can reduce future demand for water, limiting environmental degradation and easing competition for water. A 35% increase in water productivity could reduce additional crop water consumption from 80% to 20% over the next 50 years. More food can be produced per unit of water in all types of farming systems, with livestock systems deserving attention (IWMI 2007).

135. With careful targeting, the poor relying on rainfed agriculture in particular can benefit from water productivity gains in crops. Rainfed agriculture is upgraded by improving soil moisture conservation and, where feasible, providing supplemental irrigation. These techniques hold underexploited potential for lifting the greatest number of people out of poverty and for increasing water productivity, especially in Sub-Saharan Africa and parts of Asia (IWMI 2007).

136. The main pathways for enhancing water use efficiency in irrigated agriculture are to increase the output per unit of water, reduce losses of water to unusable sinks, reduce water degradation, and reallocate water to higher priority uses (Howell 2001). Many technologies have been developed to enhance the effectiveness of water use in both irrigated and rain-fed cultivation. Postel (1999) describes how micro-irrigation systems, such as drip and micro-sprinklers, often achieve efficiencies in excess of 95% compared with standard flood irrigation efficiencies of 60% or less. Other techniques for improving water use efficiency in both irrigated and rain-fed systems have included furrow diking, land levelling, direct seeding, moisture monitoring, low-energy precision application sprinklers and low pressure sprinklers (Gleick 2002). Complementary strategies have included the development of more drought-tolerant crop germplasm (Pantuwan et al. 2002), experimentation with policies that foster water markets or other economic or regulatory arrangements, and institutional reforms that engage farming communities more directly in improving water resource management (Postel 1997).

4.2.2.2 Impacts on water and soil quality.

137. Besides their effect on water quantity, agriculture can have negative impacts on freshwater quality through pollutants contained in the drainage water, runoff, and effluents. Where irrigation depletes rivers and aquifers that receive increased agricultural pollution, quality impacts are exacerbated because of reduced dilution capacity. Physical loading of water resources with inorganic (soil particles) and organic sediments, as well as chemical loading of plant nutrients, especially nitrogen, phosphorus, and pesticides, can often occur as a result of cultivation or intensive livestock and aquaculture operations (Owens 1994).

138. Two significant consequences of poor irrigation management and inadequate drainage are salinization and waterlogging (Ghassemi *et al*. 1995). Salinization occurs through the accumulation of salts deposited when water is evaporated from the upper layers of soils and is especially important in irrigated arid areas where evaporation rates are high. Since most crops are not tolerant of high salt levels,

salinization decreases yields. This problem is particularly severe in arid and semiarid areas. Waterlogging is more common in humid environments and in irrigated areas where excessive amounts of water are applied to the land. Ghassemi *et al*. (1995) estimated that around 45 million hectares, representing 20% of the world's total irrigated land, suffers from salinization or waterlogging. Losses amount to approximately 1.5 million hectares of irrigated land per year and about $11 billion annually from reduced productivity (Postel 1999), representing about 1% of the global totals of both irrigated area and annual value of production respectively (Wood *et al*. 2000).

4.2.3. Climate change

139. Agriculture and climate change are inextricably linked. As a net contributor to greenhouse gas (GHG) emissions, agriculture is part of the climate change problem. At the same time, climate change threatens agricultural production in multiple ways.

140. The yields of our most important food, feed, and fibre crops decline precipitously at temperatures much above 30°C. Among other reasons, this is because photosynthesis has a temperature optimum in the range of 20° to 25°C for many crops, and respiration increases with temperatures, leaving less photosynthates to accumulate carbohydrates, fats, and proteins in grains and other harvested products. Widespread adoption of more effective and sustainable agronomic practices can help buffer crops against warmer and drier environments, but it will be increasingly difficult to maintain or increase yields of our current major crops as temperatures rise except for certain temperate areas and tropical highlands that may actually benefit from higher average temperatures (Fedoroff *et al.* 2010).

141. Changes in precipitation patterns and increased occurrences of extreme events such as droughts and floods are expected to lead to short-run crop failures and long-run production declines. Although there may be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative. In developing countries, climate change is expected to cause yield declines for the most important crops, threatening in particular poor farming communities and smallholders (Nelson *et al*. 2009).

142. Recent estimates of global GHG emissions from different sources by the Intergovernmental Panel on Climate Change show that land use changes due to deforestation result in 18.3 percent of total GHG emission while agriculture accounts for 13.5 percent (of which agricultural soils 6 percent and livestock and manure 5.1 percent) and the transportation sector 13.5 percent (of which road transport 10 percent).

143. Carbon dioxide is released when previously-forested areas are converted into grazing land or arable land. Therefore, expansion of pasture and cropland at the expense of forests releases significant amounts of carbon dioxide into the atmosphere as does the process of pasture and arable land degradation, often associated with a net loss of organic matter. Carbon dioxide emissions also result from fossil fuel consumption used for the production of agricultural inputs (tractors, fertilizer and pesticide production, and transporting) and for the processing (drying, milling) and transport of agricultural products.

144. GHG emissions from livestock occur at the level of feed production (cultivation of feed crops, deforestation for pasture and feed crops, feed transport and soil organic matter losses in pastures and feed crops) and animal production. Methane is emitted from rumen (enteric) fermentation and from livestock waste when stored under anaerobic conditions, for example in so-called lagoons (Weary *et al*. 2008).

145. Methane and nitrous oxide are far more potent GHG than carbon dioxide on a mole-for-mole basis. The primary land-based origin of these gases is anaerobic breakdown of organic material (particularly in rice paddies). Nitrous oxide emissions originate from intensive crop production and related application of chemical fertilizers and manure. Livestock contribute about 9 percent of total anthropogenic carbon-dioxide emissions, but 37 percent of methane and 65 percent of nitrous oxide (Steinfeld *et al*. 2006).

146. Technical options are available to mitigate gaseous emissions from agriculture. Carbon-dioxide emissions can be limited by reducing deforestation and the sector can contribute to carbon sequestration through a range of practices including: restoring organic carbon in cultivated soils, reversing soil organic carbon losses from degraded pastures and sequestration through agro-forestry (Wise *et al*. 2009). Improved livestock diets as well as better manure management can substantially reduce methane emissions, while careful nutrient management (i.e. fertilization, feeding and waste recycling) can mitigate nitrous oxide emissions and ammonia volatilization. Furthermore, the use of biogas technology is a way to reduce emissions from manure management while increasing farm profit and providing environmental benefits, such as reduced fossil fuel consumption (Steinfeld *et al*. 2006, Weary *et al*. 2008).

4.3. Enhancing the use of agricultural biodiversity[17]

147. The State of the World Report on Plant Genetic Resources (SoW-PGRFA, FAO 2009) describes the current status of conservation and use of plant genetic resources for food and agriculture throughout the world. It is based on 106 country reports, two regional syntheses, several thematic studies and published literature. It describes the most significant changes that have taken place since the first State of the World's Plant Genetic Resources for Food and Agriculture was published in 1997 and describes major continuing gaps and needs.

148. The SoW-AnGRFA (2007) is the first global assessment of livestock biodiversity. Drawing on 169 Country Reports, contributions from a number of international organizations and twelve specially commissioned thematic studies, it presents an analysis of the state of agricultural biodiversity in the livestock sector – origins and development, uses and values, distribution and exchange, risk status and threats – and of capacity to manage these resources – institutions, policies and legal frameworks, structured breeding activities and conservation programmes. Needs and challenges are assessed in the context of the forces driving change in livestock production systems. Tools and methods to enhance the use and development of animal genetic resources are explored in sections on the state of the art in characterization, genetic improvement, economic evaluation and conservation.

4.3.1. Plant genetic resources

4.3.1.1. The status of conservation

In situ conservation.

149. Since the first SoW report was published (1997), a large number of surveys and inventories have been carried out, in many different countries, both in natural and agricultural ecosystems. Awareness has increased of the importance and value of crop wild relatives (CWR) and of the need to conserve them *in situ*. A global strategy for CWR conservation and use has been drafted, protocols for the *in situ* conservation of CWR are now available, and a new Specialist Group on CWR has been established within the International Union for the Conservation of Nature (IUCN)/Species Survival Commission. The number and coverage of protected areas has expanded by approximately 30% over the past decade and this has indirectly led to a greater protection of CWR. However, relatively little progress has been achieved in conserving wild PGRFA outside of protected areas or in developing sustainable management techniques for plants harvested from the wild.

150. Significant progress has been made in the development of tools and techniques to assess and monitor PGRFA within agricultural production systems. Countries now report a greater understanding of the amount and distribution of genetic diversity on farm, as well as the value of local seed systems in maintaining such diversity. More attention is now being paid in several countries to increasing genetic diversity within production systems as a way to reduce risk, particularly in light of changes in climate,

17 This section heavily leans on FAO's State of the World Report on Plant Genetic Resources (SoW-PGRFA, FAO 2009) and Animal Genetic Resources (SoW-AnGRFA, FAO 2007) for Food and Agriculture.

pests and diseases. The number of on farm management projects carried out with the participation of local stakeholders has increased somewhat and new legal mechanisms have been put in place in several countries to enable farmers to market genetically diverse varieties. There is still a need for more effective policies, legislation and regulations governing the *in situ* and on farm management of PGRFA, both inside and outside of protected areas, and closer collaboration and coordination are needed between the agriculture and environment sectors.

Ex situ conservation.

151. Since the publication of the first SoW report, more than 1.4 million accessions have been added to *ex situ* collections, the large majority of which are in the form of seeds. Fewer countries now account for a larger percentage of the total world *ex situ* germplasm holdings than was the case in 1996. While many major crops are well, even over-duplicated, many important collections are inadequately so and hence potentially at risk. For several staple crops, such as wheat and rice, a large part of the genetic diversity is currently represented in collections. However, for many others, considerable gaps remain. Interest in collecting CWR, landraces and neglected and under-utilized species is growing as land-use systems change and environmental concerns increase the likelihood of their erosion.

152. Many countries still lack adequate human capacity, facilities, funds or management systems to meet their *ex situ* conservation needs and obligations, and as a result a number of collections are at risk. While significant advances have been made in regeneration in both national and international collections, more remains to be done. The documentation and characterization of many collections is still inadequate and where information does exist, it can often be difficult to access. Greater efforts are needed to build a truly rational global system of *ex situ* collections. This requires, in particular, strengthened regional and international trust and cooperation.

153. The number of botanical gardens around the world now exceeds 2,500, maintaining samples of some 80,000 plant species. Many of these are CWR. Botanical gardens took the lead in developing the Global Strategy for Plant Conservation adopted by the Convention on Biological Diversity (CBD) in 2002. The creation of the Global Crop Diversity Trust (CGDT) and the Svalbard Global Seed Vault (SGSV) both represent major achievements since the first SoW report was published and the world's PGRFA is undoubtedly more secure as a result. However, while seed collections are larger and more secure overall, the situation has progressed less in the case of vegetatively propagated species and species whose seeds cannot be dried and stored at low temperatures.

4.3.1.2. The status of use

154. While assessing the overall extent and nature of PGRFA utilization remains difficult, its use as a basis for breeding improved crop varieties has changed little in the last decade. There appears to have been an increase in the use of PGRFA for cultural and educational purposes. Global plant breeding capacity has not changed significantly; a modest increase in the number of plant breeders has been reported in some countries and a decline in others. In many countries public sector plant breeding has continued to contract, with the private sector increasingly taking over. Considerably more attention and capacity building is still needed to strengthening plant breeding capacity in most developing countries. The number of accessions characterized and evaluated has increased in all regions but not in all individual countries.

155. Several important new international initiatives have been established that promote increased PGRFA use. The Global Partnership Initiative for Plant Breeding Capacity Building, for example, aims to enhance the sustainable use of PGRFA in developing countries through helping build capacity in plant breeding and seed systems. The Global Crop Diversity Trust (GCDT), and the new Generation and Harvest Plus Challenge Programs of the Consultative Group on International Agricultural Research (CGIAR) all support the increased characterization, evaluation and improvement of germplasm.

156. Genomics, proteomics, bioinformatics and climate change were all absent from the first SoW report but are important now, and greater prominence is also given to sustainable agriculture, biofuel crops and human health. Although progress in research and development on neglected and under-utilized species, as recommended in the first SoW report, is difficult to gauge, further efforts are needed. There is a need in many countries for more effective strategies, policies and legislation, including seed and Intellectual Property Rights (PR) legislation, to promote a greater use of PGRFA. Stronger links are needed, especially between plant breeders and those involved in seed systems, as well as between the public and private sectors.

4.3.1.3. National programmes, training needs and legislation

157. Of the 101 countries that contributed information for both the first and second SoW reports, 53% reported having a national programmes in 1996, whereas 71% report having some form of national programme now. In most countries national government institutions are the principal entities involved, however, the inclusion of other stakeholders, especially universities, has expanded. Many of the country reports noted that funding remains inadequate and unreliable.

158. Even in countries with well-coordinated national programmes, certain elements are often missing. National, publicly accessible databases, for example are still comparatively rare as are coordinated systems for safety duplication and public awareness. Since the first SoW report was published, most countries have enacted new national phytosanitary legislation, or revised old legislation, in large part in response to the adoption in 1997 of the revised International Plant Protection Convention (IPPC).

159. The importance of farmers as custodians and developers of genetic diversity was recognized in the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) through the provisions of Article 9 on Farmers' Rights. A few countries have now adopted regulations covering one or more aspects of farmers' rights.

4.3.1.4. Regional and international collaboration

160. The entry into force of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) in 2004 marks what is probably the most significant development since the publication of the first SoW report. The ITPGRFA is a legally binding international agreement that promotes the conservation and sustainable use of PGRFA and the fair and equitable sharing of the benefits arising out of their use, in harmony with the CBD. International collaboration is strongly promoted by the new ITPGRFA.

161. Given the high level of interdependence among countries with respect to the conservation and use of PGRFA, it is imperative that there be strong and extensive international cooperation. Good progress has been made in this since the first SoW report was published. A number of new regional networks on PGRFA, have been established, and a few others have become stronger. However, not all have fared well and several are largely inactive and one has ceased to function. Three new regional networks specifically addressing the issue of seed production have been established in Africa.

162. The CGIAR Centres concluded agreements in 2006 with FAO, acting on behalf of the Governing Body of the ITPGRFA, bringing their collections within the ITPGRFA's multilateral system of access and benefit sharing. There have also been many other new international initiatives including the establishment of the International Center for Biosaline Agriculture (ICBA) in 1999, the Central Asia and the Caucasus Association of Agricultural Research Institutions (CACAARI) and the Global Forum on Agricultural Research (GFAR) in 2000, the Forum for Agricultural Research in Africa (FARA) in 2002, the Global Cacao Genetic Resources Network (CacaoNet) in 2006, and Crops for the Future and the SGSV in 2008. All have significant activities in PGRFA. In the area of funding, several new foundations now support international activities in PGRFA, a special fund to support agricultural research in Latin

America (FONTAGRO) was set up in 1998, and in 2004 the GCDT was established as an essential element of the funding strategy of the ITPGRFA.

4.3.1.5. Access to PGR, the sharing and benefits derived from their use and the realization of farmer rights

163. The international and national legal and policy framework for access and benefit sharing (ABS) has changed substantially since the publication of the first SoW report. The entry into force in 2004 of the ITPGRFA established a Multilateral System of ABS that facilitates access to plant genetic resources of the most important crops for food security, on the basis of a Standard Material Transfer Agreement (SMTA). As of June 2009 there were 120 Parties to the ITPGRFA. Negotiations under the CBD to develop an international regime on ABS are scheduled to be finalized in 2010. However, many issues remain to be settled, including the legal status of the regime. Discussions on matters related to ABS are also taking place in other fora such as the Trade-Related Aspects of Intellectual Property Rights Council, the World International Property Organization and the World Trade Organization. There is a need for greater coordination among the different bodies involved in these discussions at the national as well as international levels.

164. In February 2009, the CBD Database on ABS Measures listed 30 countries with legislation regulating ABS. Of these, 22 had adopted new laws or regulations since 2000. Most have been developed in response to the CBD rather than the ITPGRFA. Many countries have expressed a desire for assistance in confronting the complex legal and technical issues involved in drawing up new legislation. So far there are few models that can be emulated and several countries are experimenting with new ways of protecting and rewarding traditional knowledge and realizing Farmers' Rights.

4.3.1.6. The contribution of PGRFA to food security and sustainable agricultural development

165. Schemes that promote Payment for Ecosystem Services - such as the *in situ* or on farm conservation of PGRFA - are being set up in an attempt to encourage and reward farmers and rural communities for their stewardship of the environment. However, the fair and effective implementation of such schemes remains a major challenge.

166. Concerns about the potential impact of climate change have grown substantially over the past decade. PGRFA are becoming recognised as being critically important for the development of farming systems that capture more carbon and emit fewer greenhouse gases, and for underpinning the breeding of the new varieties that will be needed for agriculture to adapt to the anticipated future environmental conditions. Given the time needed to breed a new crop variety, it is essential that additional plant breeding capacity be built now.

167. There is a need for more accurate and reliable measures, standards, indicators and baseline data for sustainability and food security that will enable a better monitoring and assessment of the progress made in these areas. Of particular need are standards and indicators that will enable the monitoring of the specific role played by PGRFA.

168. In spite of the enormous contribution by PGRFA to global food security and sustainable agriculture, its role is not widely recognized or understood. Greater efforts are needed to estimate the full value of PGRFA, to assess the impact of its use and to bring this information to the attention of policy makers and the general public so as to help generate the resources needed to strengthen programmes for its conservation and use.

4.3.2. Animal genetic resources

4.3.2.1. The state of conservation and use

169. Animal genetic diversity is essential to global food security, sustainable development and the livelihoods of hundreds of millions of people. The livestock sector and the international community are facing many challenges. The rapidly rising demand for livestock products in many parts of the developing world, emerging animal diseases as well as climate change and global targets such as the Millennium Development Goals need to be urgently addressed. Many breeds have unique characteristics or combinations of characteristics – disease resistance, tolerance of climatic extremes or supply of specialized products – that could contribute to meeting these challenges.

170. However, evidence suggests that there is ongoing and probably accelerating erosion of the genetic resource base. FAO's Global Databank for Animal Genetic Resources for Food and Agriculture contains information on a total of 7 616 livestock breeds. Around 20 percent of reported breeds are classified as at risk. Of even greater concern is that during the first six years of this century 62 breeds became extinct – amounting to the loss of almost one breed per month. These figures present only a partial picture of genetic erosion. Breed inventories, and particularly surveys of population size and structure at breed level, are inadequate in many parts of the world. Population data are unavailable for 36 percent of all breeds. Moreover, among many of the most widely used high-output breeds of cattle, within-breed genetic diversity is being undermined by the use of few highly popular sires for breeding purposes.

4.3.2.2. Threats to animal genetic resources

171. A number of threats to genetic diversity can be identified. Probably the most significant is the marginalization of traditional production systems and the associated local breeds, driven mainly by the rapid spread of intensive livestock production, often large-scale and utilizing a narrow range of breeds. This is driven by a number of factors including the rapid spread of intensive livestock production, degradation or loss of access to natural resources (particularly grazing land), changing livelihoods and lifestyles, and poorly planned policies, development interventions and livestock management (particularly indiscriminate cross-breeding). Global production of meat, milk and eggs is increasingly based on a limited number of high-output breeds – those that are most profitably utilized in industrial production systems. The intensification process has been driven by rising demand for animal products and has been facilitated by the ease with which genetic material, production technologies and inputs can now be moved around the world. Intensification and industrialization have contributed to raising the output of livestock production and to feeding the growing human population. However, policy measures are necessary to minimize the potential loss of the global public goods embodied in animal genetic resource diversity.

172. Acute threats such as major disease epidemics and disasters of various kinds (droughts, floods, military conflicts) are also a concern – particularly in the case of small, geographically concentrated breed populations. Threats of this kind cannot be eliminated, but their impacts can be mitigated. Preparedness is essential in this context as ad hoc actions taken in an emergency situation will usually be far less effective. Fundamental to such plans, and more broadly to the sustainable management of genetic resources, is improved knowledge of which breeds have characteristics that make them priorities for conservation, and how they are distributed geographically and by production system.

173. Where the evolution of livestock production systems threatens the ongoing use of potentially valuable genetic resources, or to safeguard against sudden disastrous losses, breed conservation measures have to be considered. Where feasible, facilitating the emergence of new patterns of sustainable utilization should be an objective. Particularly in developed countries, niche markets for specialized products, and the use of grazing animals for nature or landscape management purposes, provide valuable opportunities. Well-planned genetic improvement programmes will often be essential if local breeds are to remain viable livelihood options for their keepers.

4.3.2.3. The state of the art in the management of animal genetic resources

174. Management of AnGR requires methods for characterization, genetic improvement, economic analysis and conservation. Characterization involves the identification, description and documentation of breed populations and the habitats and production systems in which they were developed and to which they are adapted. One aim is to provide an assessment of how well particular breeds will perform within the various production systems found in a country or region, and thus to guide farmers and development practitioners in their decision-making. Another objective is to provide the information that is needed for planning conservation programmes.

175. An important aspect of the characterization process is to make relevant data available to a wide range of stakeholders, including policy-makers, development practitioners, livestock keepers and researchers. Existing public domain information systems need to be further developed to expand their content and allow users easier access to the data they require. Linking breed data to environment and production system maps would be an important aid to decision-making.

176. Great progress has been made in genetics and reproductive biotechnology, which has enabled rapid advances in highly controlled production systems. However, there is urgent need to design and implement programmes that are appropriate for low external input production conditions. For many local breeds, genetic improvement is likely to be essential if their utilization is to remain economically viable. Methods for the establishment of stable cross-breeding programmes that involve the maintenance of pure-bred herds or flocks of local breeds need to be investigated.

177. The large number of breeds that are at risk and the limited financial resources available for conservation and breed development imply that economic analysis of the value of the genetic resources at stake and of potential management interventions is necessary to guide decision-making. Important tasks include: 1) determining the economic contribution that particular animal genetic resources make to various sectors of society; 2) identifying cost-effective conservation measures; and 3) designing economic incentives and policy/institutional arrangements for the promotion of conservation by individual farmers or communities.

178. Methods for the economic valuation of animal genetic resources have been slow to emerge owing to the limited availability of the data required. Despite the problems, a growing number of economic studies in this field are being undertaken. Important points emerging from such studies include inter alia: 1) Adaptive traits and non-income functions are important components of the total value of indigenous breed animals; 2) The costs of implementing an in situ breed conservation programme may be relatively small, both when compared to the size of subsidies currently being provided to the commercial livestock sector and when compared to the benefits of conservation; 3) Conservation policy needs to promote cost-efficient strategies.

179. Effective management of animal genetic diversity requires resources – including well-trained personnel and adequate technical facilities. Sound organizational structures (e.g. for animal recording and genetic evaluation) and wide stakeholder (particularly breeders and livestock keepers) involvement in planning and decision-making are also essential. However, throughout much of the developing world, these prerequisites are lacking. According to in country reports submitted between 2002 and 2005, 48% of the world's countries report no national-level *in vivo* conservation programmes, and 63% report that they have no *in vitro* programmes. Similarly, in many countries structured breeding programmes are absent or ineffective.

4.3.2.4. Needs and challenges in animal genetic resources management

180. The livestock sector has to balance a range of policy objectives. Among the most urgent are: supporting rural development and the alleviation of hunger and poverty; meeting the increasing demand

for livestock products and responding to changing consumer requirements; ensuring food safety and minimizing the threat posed by animal diseases; and maintaining biodiversity and environmental integrity. Meeting these challenges will involve mixing species, breeds and individual animals with the qualities needed to meet the specific requirements of particular production, social and market conditions. However, there are many constraints to meeting the goal of matching genetic resources to development needs.

181. Inventory and characterization are fundamental to the management of animal genetic resources, but remain far from complete, particularly in developing countries. Addressing the knowledge gaps that impede decision-making should be a priority. The current rate of genetic erosion also gives cause for significant concern. Well-targeted conservation measures to address threats to particular breeds are essential. However, there is an emerging consensus that the real requirement is for sustainable approaches to use and development, both for individual breeds and for animal genetic diversity as a whole. There is a need to establish principles and elements that underpin effective management, balance current and future use, and address economic, social and environmental concerns. Community-level programmes that both support the livelihoods of the livestock keepers involved and address global concerns about biodiversity are required. Initiatives of this type must be backed up by strengthened institutional and organizational structures, and policy and legal frameworks that support sustainable development.

182. The countries and regions of the world are interdependent in the utilization of animal genetic resources. This is clear from evidence of historic gene flows and current patterns of livestock distribution. In the future, genetic resources from any part of the world may prove vital to breeders and livestock keepers elsewhere. There is a need for the international community to accept responsibility for the management of these shared resources. Support for developing countries and countries with economies in transition to characterize, conserve and utilize their livestock breeds is necessary. Wide access to animal genetic resources, for farmers, herders, breeders and researchers, is essential to sustainable use and development. Equitable frameworks for access, and for sharing the benefits derived from animal genetic resources, need to be put in place at both national and international levels. Indeed, a number of countries have developed or are developing national strategies and action plans for AnGR. International cooperation at all levels, from research to institutional and legal arrangements, and better integration of animal genetic resources management into all aspects of livestock development, can help to ensure that the world's wealth of livestock biodiversity is suitably used and developed, and remains available for future generations.

4.4. Supportive policies

4.4.1. Encouraging resource-use efficiency

183. In the recent past, increased agricultural productivity has been derived from genetic improvement and greater use of external inputs (fossil energy, fertilizers, feed, pesticides, and irrigation water). Now, the focus needs to shift to increasing resource-use efficiency. Resource-use efficiency is the key to lessening the environmental impact of crops and livestock. According to (Spiertz & Oenema 2005) a combination of systems innovations, development of best practices and legislation turned out to be effective in developing more environment-friendly agricultural systems in The Netherlands and in rice-based cropping systems in Asia. These authors contend that in many cases the resource-use efficiency (water, nutrients) can be raised by a factor 2 to 4. This holds especially for animal production systems, but also for crop production systems. Policies toward increasing water use efficiency will have to encourage the identification of improved engineering and agronomic solution, aim at reducing losses of water to unusable sinks and water degradation, and reallocate water to higher priority uses (Howell 2001).

184. More technological and management options for improved resource-use efficiency need to be identified through research, to make agriculture more sustainable. But for these to be widely adopted will require adequate price signals, more closely reflecting the true scarcities of production factors, and

correcting the distortions that currently provide insufficient incentives for efficient resource use. Prices of land, water and agricultural inputs do not reflect true scarcities. These leads to an overuse of these resources by agriculture and to major inefficiencies in the production process (Steinfeld *et al*. 2006). Any future policy to protect the environment will, therefore, have to introduce adequate market pricing for agricultural inputs. Water in particular is over used and under valued in many countries but there is a growing experience with providing incentives to farmers to manage and use water more sustainably (see UNEP/CBD/SBSTTA/14/INF/3 for further discussion).

185. Mandatory taxes on agricultural inputs could be used as regulatory instruments to induce greater resource use efficiency and environmental stewardship. Taxation is widely believed to be more cost-effective than command-and-control regulations and to be more likely to spur innovation. For example, N fertilizer could be taxed to reduce its use and to encourage appropriate use of manure. It is, however, difficult to reach specific targets in pollution reduction using the taxation approach, since regulators have difficulty predicting how polluters will react (NRC 2000).

186. In the case of pastures, suggested instruments include the introduction and adjustment of grazing fees and lease rates, and improved institutional arrangements for controlled and equitable access. Further, the removal of price support at product level (i.e. the production subsidies for livestock products in most industrialized countries) is likely to improve technical efficiency (Steinfeld *et al.* 2006).

4.4.2. Correcting for negative environmental externalities

187. Agricultural production has important negative "externalities," namely effects on the environment or economy that are not reflected in the cost of food. Negative externalities include the release of greenhouse gases, water shortages due to over-extraction, soil degradation and the loss of biodiversity through land conversion or inappropriate management (Godfray 2010).

188. Although the removal of price distortions at input and product level as outlines in the preceding paragraph will go a long way to enhancing the technical efficiency of natural resources use in agriculture, this may often not be sufficient. Environmental externalities, both positive and negative, need to be explicitly factored into the policy framework, through the application of the “provider gets-polluter pays” principle.

189. Correcting for distortions and negative externalities, both positive and negative will bring agriculture closer to the true scarcities of production factors and natural resources used. Eventually this will lead farmers into management choices that make better use of resources and limit pollution and waste. Farmers who provide environmental services need to be compensated, either by the immediate beneficiary (such as with improved water quality for downstream users) or by the general public (FAO 2007b).

190. Research and development of new technologies and practices that reduce the trade-offs between food provision and other ecosystem services, and environment-related regulation and enforcement systems for the agriculture sector constitute other options of reducing agriculture’s negative externalities. But the principle of engaging the potential beneficiaries of improved cultivation practices in some form of dialogue with producers continues to define new institutional arrangements to better manage production externalities. Examples are watershed user groups, commodity boards, organic certification systems, and trading of carbon credits (MEA 2005).

191. The taxation of environmental damage and incentives for environmental benefits needs to be much more rigorously applied in future, tackling local externalities first but increasingly also trans-boundary impacts, through the application of treaties, underlying regulatory frameworks and market mechanisms. Government policies may be required to provide incentives for institutional innovation in that regard.

192. The costs for higher input prices and environmental controls will have to be passed on to the consumer, in the form of higher prices of animal products, for example of beef, the production of which entails much environmental degradation in a wide range of production intensities and scales (CAST 1999).

193. Accounting for negative externalities will also assist in reducing waste. Godfray *et al.* (2010) point out that roughly 30 to 40% of food in both the developed and developing worlds is lost to waste. In rich countries (and to rich consumers in poor countries) food is relatively cheap. Consumers have become accustomed to purchasing foods of the highest “cosmetic standards”; hence, retailers discard many edible, yet only slightly blemished products. Commercial pressures can encourage waste. Litigation and lack of education on food safety have lead to a reliance on "use by" dates, whose safety margins often mean that food fit for consumption is thrown away. In some developed countries, unwanted food goes to a landfill instead of being used as animal feed or compost because of legislation to control prion diseases.

194. If food prices were to rise again, it is likely that there would be a decrease in the volume of waste produced by consumers in developed countries. Waste may also be reduced by alerting consumers to the scale of the issue, as well as to domestic strategies for reducing food loss. Advocacy, education, and possibly legislation may also reduce waste in the food service and retail sectors. Legislation such as that on sell-by dates that has inadvertently increased food waste should be re-examined (Godfray *et al*. 2010).

195. Accounting for negative externalities in animal production will increase meat prices and may well induce shifts in dietary habits as well, particularly toward decreasing (or not further increasing) meat consumption where appropriate. The conversion efficiency of plant into animal matter is ~10%; thus more people could be supported from the same amount of land if diets became less carnivorous. Reducing the consumption of meat (and increasing the proportion that is derived from the most efficient sources) offer an opportunity to feed more people and also present other advantages. Well-balanced and diverse diets rich in grains and products sourced from local crop biodiversity are considered to be more healthful than those containing a high proportion of meat (especially red meat) and highly refined carbohydrates. As developing countries consume more meat in combination with high-sugar and -fat foods, they may find themselves having to deal with obesity before they have overcome under-nutrition, leading to an increase in spending on health that could otherwise be used to alleviate poverty (Godfray *et al*. 2010).

4.4.3. Rewarding farmers for the provisioning of environmental services

196. Agriculture has the potential to provide enhanced levels of environmental services alongside the production of food and other products. Two forces are generating a growth in demand for environmental services: a greater awareness of their value; and their increasing scarcity, arising from mounting pressures on ecosystems. However, farmers mostly lack incentives to consider the impacts of their decisions on environmental services. Improved information and regulations can influence farmers’ decisions in ways that enhance the environment – as can payments to farmers from those who benefit (FAO 2007b).

197. In richer countries, public funds are increasingly being used to provide incentives for producers to take greater account of the external negative impacts of production. These have included investments in payments to producers to help offset the additional costs of environmentally friendly practices. Examples of actions that could be rewarded include land management and vegetative covers that maintain or restore biodiversity; or the sequestration of carbon in stable organic matter through pasture management, the shift from annuals to perennials, and conservation tillage. National farm policies should be designed to reduce nutrient leakage from agriculture by improving the economic return of those farmers who appropriately reduce fertilizer use and reducing economic subsidies to those farmers who exceed recommended fertilization levels. Incentive payments could be used that, nationally or in specific watersheds, encourage farmers to adopt practices that reduce N losses (as described in section 4.2.1. Regulations or marketable permits that charge farmers for N runoff above a set limit could also be applied (MEA 2005, FAO 2007b).

198. Payments for environmental services in poor countries should not primarily be conceived as a poverty reduction tool, although the poor are likely to be affected and payments can increase the incomes of farmers who produce environmental services. The distribution of benefits depends on who produces the environmental services, and where. In some cases, payments may also have adverse impacts on poverty and food security, for example if they reduce agricultural employment or increase food prices. Nevertheless, Payment for Environmental Services (PES) programmes have been shown to be potentially accessible and beneficial to the poor if properly designed (Thies 2000, FAO 2007b).

199. PES schemes have tended to focus on carbon sequestration and storage, non-domesticated biodiversity conservation, watershed protection and protection of landscape aesthetics. There needs to be more explicit consideration of PES in the context of agrobiodiversity conservation. This is fraught with a number of methodological problems. With the exception of wild relatives, agrobiodiversity is not an "open access common," such as wildlife. It is managed privately or in communities, either for subsistence or commercial purposes. Another problem is that market prices do not reflect the real value of agrobiodiversity and its services because of a failure to internalize external costs (Thies 2000). Nevertheless, "payment for agrobiodiversity conservation services" (PACS) schemes are currently under study to permit the "capture" of public conservation values at the farmer level, thereby creating incentives for the conservation of agrobiodiversity and supporting poverty alleviation[18].

4.4.4. Increasing investments in agriculture and agricultural research

200. For most of the past 25 years, investment in agriculture has declined relentlessly. In 2005 most developing countries were investing only around 5% of public revenues in farming. The share of aid going to agriculture fell by around three-quarters between 1980 and 2006. From 1986 to 2007, agricultural ODA from the US and the EU targeted to small farmers in poor countries was $1.01 and $2.46 per farm, respectively, compared to an annual average of $17,765 (US) and $7,614 (EU) per farm from 1986 to 2007 in donor countries (Oxfam 2009).

201. Faltering public commitment to investing in agriculture in developing countries hampers farmers' ability to cope with climatic and economic shocks, to pull themselves out of poverty and to deliver the ecosystem services demanded by society. Even though investments did occur, they were insufficient in magnitude, inadequate in scope, and inequitably distributed, and therefore unable to address the needs of many agricultural communities, particularly those of smallholders, women and workers in marginalized areas (Oxfam 2009). During the Green Revolution of the 1960s, staple-crop yields were rising by 3-6% a year. Today they are rising by only 1-2% a year, or not at all as in some poor countries. At the global level, the rate of increase in cereal yields is falling below the rate of projected demand (MEA 2005).

202. As section 4.2 has shown there is no lack of improved production technologies. Given the large market and policy failures, under which agriculture operates, there is still a huge amount of progress that can be achieved from wide adoption of existing tried and tested technologies (Steinfeld *et al.* 2006). However, in the face of emerging challenges such as those arising from climate change, there is currently imperfect knowledge of how agriculture can intensify sustainably and greater investments in agricultural science and technology are needed to meet the demands of a growing world population.

203. Where governments have invested in agricultural research and extension, productivity growth rates have been higher and area expansion rates often lower. This has contributed significantly to agricultural growth and rural poverty reduction in rural areas, and to urban poverty reduction through lower food prices. Without such investments, agricultural and national economic growth would have been much slower, and many more rural and urban people in developing countries would be poor (MEA 2005).

18 http://www.bioversityinternational.org/scientific_information/themes/economics/on_going_and_pipeline_projects.html

204. Experiences in India, China, Vietnam, Thailand, and Uganda have shown that public investments in agricultural research, education, and rural infrastructure are the three most effective types of public spending for promoting agricultural growth and reducing poverty (Fan *et al.* 2007). Published estimates of nearly 700 rates of return on R&D and extension investments in the developing world average 43 percent a year (Alston *et al*. 2000), however agricultural R&D continues to be notoriously under-funded owing to a variety of reasons. Public expenditure decisions tend to emphasize short-term payoffs and subsidies that are "politically visible" rather than long-term investments (World Development Report 2008).

205. Evidence for the effectiveness of public agricultural research also comes from a study modelling the potential impact on agricultural (food) production and poverty reduction of doubling research investments by international research centres of the Consultative Group on International Agricultural Research (CGIAR). The modelling indicates that increasing investment in public agricultural research in the countries included in the model from about US$4.6 billion to US$9.3 billion during five years (2008–13), and doubling CGIAR investment from US$0.5 to US$1.0 billion as part of that, would increase output growth coming from research and development (R&D) from 0.53 to 1.55 percentage points. Doubling this R&D investment would also reduce $1-a-day poverty by 204 million people by 2020 (Von Braun *et al.* 2008).

206. Von Braun *et al*. (2008) describe 14 examples of "best bets" for large-scale research investments, ranging between about US$10 million and US$150 million each over five years. They encompass the broad areas of increasing the agricultural productivity of crop and livestock systems, reducing risks, improving the nutritional quality of food, mitigating climate change and improving ecosystem resilience, enhancing germplasm exchange, and improving market information and value chains.

207. Godfray *et al*. (2010) emphasize that the lack of adequate metrics of agricultural sustainability is a major problem when evaluating alternative strategies and negotiating trade-offs. This is the case for relatively circumscribed activities, such as crop production on individual farms, and even harder when the complete food chain is included or for complex products that may contain ingredients sourced from all around the globe. There is also a danger that an overemphasis on what can be measured relatively simply (carbon, for example) may lead to dimensions of sustainability that are harder to quantify (such as biodiversity) being ignored. These are areas at the interface of science, engineering, and economics that urgently need more attention.

208. There is also an urgent need for a better understanding of the effects of globalization on the full food system and its externalities. Because the expansion of food production and the growth of population both occur at different rates in different geographic regions, global trade is necessary to balance supply and demand across regions. However, the environmental costs of food production might increase with globalization, for example, because of increased greenhouse gas emissions associated with increased production and food transport. An unfettered market can also penalize particular communities and sectors, especially the poorest who have the least influence on how global markets are structured and regulated (Pretty *et al*. 2005).

4.4.5. Empowering poor farmers

4.4.5.1 Strengthening agricultural extension services.

209. Success in agricultural development and sustainability depends on individual actions of hundreds of millions of rural families, whose decisions are shaped by the information, knowledge and technologies available to them. For example, during the Green Revolution, particularly in Asia, public extension systems did contribute significantly to the dissemination of new technologies for staple food crops (Swanson 2008). However, policies to bring down public deficits in many developing countries have led to the dismantling or reduction of agricultural extension systems and the introduction of fee-based

schemes. This has been portrayed as a positive development: Users can dictate, or at least influence, the type and quality of the services they buy. On the other hand, it has put advisory services beyond the reach of the poorest (Neuchatel Initiative 2007).

210. Many countries have recognized the need to reinvigorate agricultural extension or advisory services as a means of using agriculture as an engine of pro-poor growth; reaching marginalized, poor, and female farmers; and addressing new challenges, such as environmental degradation and climate change. A study based on 294 studies worldwide, estimated the annual rates of return on extension investments were 79 percent (Alston *et al.* 1999). However, in spite of ample experience with extension reform worldwide, identifying the reform options most likely to make extension more demand-driven remains a major challenge (Birner and Anderson 2007).The concept of demand-driven services implies making extension more responsive to the needs of all farmers, including women and those who are poor and marginalized. Sound agricultural policies are also a precondition for agricultural extension to achieve its purpose (Neuchatel Group 2007).

211. Where they still exist, today's national agriculture research and extension systems face many challenges and opportunities. Serious limitations in planning and financial management of agricultural research, in the organization and management of the research institutions and in technology transfer strategies have been identified through several analyses and assessments. Similarly, extension systems are often under-resourced and use outdated service provision approaches and extension methods. At the same time, developments in biotechnology and biosafety, climate change concerns, food insecurity, the growing relevance of agri-food chains, demands for greater rural producer empowerment, and in the changes in information and communication technologies combine to provide many new opportunities for growth and renewal for national agriculture research and extension systems (Swanson 2008).

212. Recognizing that the poorest of the poor will likely be hardest hit climate change, Nelson *et al* (2009) highlight the importance of extension programs to address mitigation of, and adaptation to, climate change, in terms of the need of disseminating local cultivars of drought-resistant crop varieties, teaching improved management systems, and providing an effective information-sharing mechanism farmer communities and government efforts.

4.4.5.2 Recognition of gender issues

213. Women play an essential role in achieving food security. While women play a critical role and have multiple responsibilities within the household and communities in securing healthy nutrition, their realities are often ignored at all levels of decision-making. Where viable, investment in the social and economic mechanisms to enable improved small-holder yields, especially where targeted at women, can be important means of increasing the income of both farm and rural non-farm households (Godfray 2010). Women farmers account for some 60–80% of food production in many developing countries. They produce more than half the world's food and own 1% of the land. Response polices need to be gender sensitive and designed to empower the women by providing knowledge and ensuring access and control of resources toward achieving food security (MEA 2005).

4.4.5.3 Land tenure

214. Poverty is also often associated with a lack of security in terms of access to or title to land and other natural resources, in turn diminishing farmers' incentives and ability to choose production practices with long-term payoffs. Without such incentives, farmers often focus on meeting short-term needs, and increasingly intensive cultivation under such conditions has often resulted in the degradation of soil and water resources that are required to maintain even low levels of productivity (MEA 2005).

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ACRONYMS

AAPG	Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity
AgBD	Agricultural biodiversity
AnGR	Animal Genetic Resources
CBD	Convention on Biological Diversity
COP	Conference of the Parties
CGDT	Global Crop Diversity Trust
CWR	Crop Wild Relatives
GHG	Greenhouse gas
GMO	Genetically Modified Organism
GPA	Global Plan of Action for Plant Genetic Resources
GPA-AnGR	Global Plan of Action for Animal Genetic Resources
GRFA	Genetic resources for food and agriculture
FAO	Food and Agriculture Organization of the United Nations
IPR	Intellectual Property Rights
IFOAM	International Federation of Organic Agriculture Movements
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUCN	International Union for the Conservation of Nature
N	Nitrogen
NFR	EU Novel Food Regulation
P	Phosphorus
PACS	Compensating Farmers through Payment for Agrobiodiversity Conservation Services
PES	Payment for Environmental Services
PGR	Plant Genetic Resources
PoW	CBD Programme of Work
R&D	Research and Development
SoW	State of the World
UPOV	International Union for the Protection of New Varieties of Plants (UPOV)