Food Security, Biofuels and Agriculture:

Major Drivers of Biodiversity Loss and an Opportunity for Sustainability?

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Vision for a MacArthur program on agriculture and biodiversity: The proposed program builds on MacArthur's conservation and sustainable development portfolio and supports MacArthur's aims of landscape conservation and innovation in dealing with trade-offs. It could also bridge the different themes within the MacArthur Foundation's program. The program covers steps needed to integrate biodiversity concerns into landscapes in a world where agriculture will likely dominate over the next 40 years and includes: (i) data synthesis, integration and mapping in areas earmarked for agricultural expansion to assess the potential impacts (ii) development of cross-sectoral policy, and institutional approaches and novel management to integrate biodiversity and agriculture across the landscape; and (iii) development of tools to assess the effectiveness of site-based approaches to address landcover change, as in protected areas. Results of the program would be expected to include improvements in integrating biodiversity and agriculture policy and practice at the landscape level to maintain ecosystem services and contribute to the proposed CBD post 2010 target ***"By 2020, to: reduce the pressures on biodiversity; prevent extinctions; restore ecosystems; and enhance ecosystem services, while equitably sharing the benefits, thus contributing to human well-being and poverty eradication, and to have provided the means for all Parties to do so."***

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Executive Summary

The challenge of ensuring food security without destroying biodiversity

Agriculture will need to supply 70% more food for a growing and increasingly wealthy human population by 2050, as well as perhaps a 90% increase in oil crops for renewable fuels by 2018. Over the past 300 years, agriculture has been responsible for grave damage to ecosystems and biodiversity: some 43% of the world's land surface has been converted to agriculture, 60% of vertebrate species are threatened by it and there are further impacts from herbicide, pesticide and fertilizer use. Demand for increased agricultural production could thus present a serious threat to biodiversity. Yet, there is reason for optimism. The recent international focus on agriculture and food security and the rethinking of economic approaches present an opportunity for the MacArthur Foundation to make a major contribution to shaping biodiversity and agricultural policy in the coming decades.

It is time for those who argue that biodiversity is a fundamental foundation of human well-being to engage more meaningfully with the agricultural sector and with the burgeoning public-private partnerships seeking to address food security issues. So far, biodiversity conservation has generally failed to gain the necessary attention when trade-offs are negotiated in agricultural policy because its value, and that of ecosystem services, is still poorly understood. This marginalization of biodiversity has been inadvertently compounded by the way that the Convention on Biological Diversity (CBD) splits 'natural' biodiversity and 'agricultural biodiversity' into separate work programs. It is now imperative that human needs and threats are seen as part of whole landscapes that have to be managed sustainably.

Case studies in the Democratic Republic of Congo, Madagascar and Kenya highlight some effective tools and approaches that could be disseminated in other high priority areas. They also show that concerted effort over the next few years could develop new approaches to the joint challenges facing agriculture and biodiversity. These must take account of agriculture's contribution to development of the rural poor and of an increasing interest in sustainable agriculture by agribusiness. Some that show promise include payments for ecosystem services, integrated landscape planning, conservation and precision agriculture. As new approaches are developed, tools will be needed to assess their effectiveness and stakeholders and wider society need to be engaged in land stewardship and making decisions.

Summary Recommendations

We propose a program that builds on MacArthur's conservation and sustainable development portfolio and supports its aims of landscape conservation and innovation in dealing with trade-offs. The program outlines steps needed to integrate biodiversity concerns into landscapes in a world where agriculture will likely dominate over the next 40 years. It includes: (i) data synthesis, integration and mapping in areas earmarked for agricultural expansion to assess the potential impacts (ii) integrating biodiversity and agriculture across the landscape by developing cross-sectoral policy and novel management methods; and (iii) developing tools to assess the effectiveness of site-based approaches to address land-cover change, particularly in protected areas.

Impacts of such a program would include contributing to maintaining ecosystem services and to the proposed CBD post 2010 target "By 2020, to: reduce the pressures on biodiversity; prevent extinctions; restore ecosystems; and enhance ecosystem services, while equitably sharing the benefits, thus contributing to human well-being and poverty eradication, and to have provided the means for all Parties to do so." The impact of

MacArthur's work in this area could be magnified by looking for co-benefits with foundations in the agricultural sector.

Data synthesis, integration and mapping

If concerns for ecosystems are to be better factored into decisions about agriculture, there needs to be more robust evidence of the relationships between the two and better projections of future changes. First, we need to assess the models that predict future demand for agricultural products and hence of land-use change, including a critical evaluation of assumptions underpinning current models. Second, we need better projections of the impacts of agricultural change. Maps of potential impacts at local, national and global scales would identify important biodiversity areas at risk, for example in the areas earmarked for agricultural expansion in Latin America and sub-Saharan Africa. This will need compilation of data on biodiversity, ecosystem services and socio-economic factors associated with agricultural developments.

We need to document and predict the impacts of agriculture on biodiversity and understand which agricultural systems are productive and still protect biodiversity and ecosystem services.

Integrating biodiversity and agriculture in policy and practice

At present, biodiversity and agriculture professionals work in separate spheres, but the challenges facing each can best be met by working together. In this way, both could understand and manage differences in priorities. They could also better evaluate and distribute novel approaches to integrated land management, such as through agri-environment schemes and payments for ecosystem services for example for carbon sequestration in agricultural lands.

Softening the distinctions between agriculture and conservation might allow the movement of species through a matrix of agricultural and other land-uses. By examining where and how such connectivity has been achieved and assessing its impacts, lessons can be learned that inform future action in a world dealing with climate change. We also need to understand the links between patterns of consumption and landscape change.

Developing assessment tools

MacArthur could build on its previous investment in evaluating conservation outcomes by supporting work on tools to assess changes in land-cover rapidly. There is an opportunity to do this by combining advances in remote sensing with citizen science and the spatial mapping tools and databases available via the worldwide web.

Generating co-benefits between Foundations

The MacArthur Foundation could influence major players in the development arena by working with foundations that support agricultural work. For example, the Gates Foundation supports agricultural research and data collection in sub-Saharan Africa. By supporting a complementary program to collect and map relevant data on biodiversity and ecosystem services, MacArthur could promote better data integration and planning for integrated landscape management and build a cadre of local professionals who can act to maintain biodiversity and deliver agricultural production.

1. Introduction

Agricultural food production will need to be increased by 70% over the next 40 years or so to meet the demands of a growing and increasingly wealthy human population (Bruinsma 2003; FAO 2010). Biofuel crops have already displaced food production in some areas and led to further deforestation. This will become more common as more governments legislate to increase the use of renewable fuels (Cotula et al. 2009). This agricultural growth must be achieved in a world where agriculture is already responsible for 70% of global water use and conversion of 35% of terrestrial land area and where there is a pressing need to reduce soil degradation, fossil fuel use, deforestation and biodiversity loss (MEA 2005).

There is no consensus on how this increased production will be achieved. A second 'green revolution' might avoid too much more encroachment on the world's remaining biodiversity (Conway 1997). Or at worst, more and more land may be converted to agricultural production, destroying biodiversity at a scale and rate more severe than any the Earth has previously experienced (Lawton and May 1995; Verburg et al. 2009). Under either scenario, those who believe that biodiversity forms the foundation of human well-being must engage more meaningfully with the agricultural sector. Concerns about biodiversity must be incorporated into agricultural science, policy and practices, and trade-offs must be negotiated that will feed the world in 2050.

Novel approaches will be required. The recent international focus on agriculture and food security, and the rethinking of economic approaches following the 2008 banking collapse present a major opportunity for the conservation community, which needs to recognise economic constraints under which farmers and land-users often operate. The biodiversity sector needs to demonstrate the full value of ecosystem services and of biodiversity to agriculture and human society more widely. However, many conservationists remain focussed on conventional regulatory and preservationist approaches. These are important conservation tools but recent analyses have confirmed that protected areas are insufficiently extensive or representative to encompass all threatened species (Leader-Williams et al. 1990; Rodrigues et al. 2004). Many conservationists argue for increases in the size of the current protected area estate (CBD 2010). But protected areas are socially and economically contentious, and other approaches to conservation urgently need attention (Brockington and Igoe 2007).

Conservation has been marginalised in decisions over land-use. Arguably, this has been institutionalised through splitting of biodiversity into agricultural and wider biodiversity under the Convention of Biological Diversity, perpetuating divisions in terms of land management at the both landscape and policy levels. The FAO and national agriculture departments have continued to deal with 'production landscapes', with a mandate to increase production whilst biodiversity has largely been sidelined to the CBD and environment departments. The latter rarely have meaningful budgets or strong voices in national government, even though many now recognise that the value of ecosystem services provided by the functioning environment is significant (Balmford et al. 2002; MEA 2005). The CBD has called for the integration of biodiversity into production landscapes, but this has yet to be fully implemented.

To stand a chance of success in addressing climate change and maintaining ecosystem services, the conservation community must bring its concerns centre stage and work with the agricultural sector. Working together, they will need to finds ways of valuing the full variety of benefits that ecosystems provide and recompensing those that manage land sustainably to balance human and environmental needs. Those who wish to gain a stronger negotiating position for biodiversity concerns in future agricultural policy will need to be able to refer authoritatively to the wealth of experiences, both good and bad, within the biodiversity science community and inform the discussion with the best available knowledge on biodiversity and ecosystem services.

To develop a program for change, in this paper we argue for better integration of the traditionally separate sectors of agriculture and biodiversity, recognizing that both agricultural production and biodiversity conservation are economic and social imperatives for human well-being. We first review the benefits of agriculture, the challenges it poses to the environment and question how production may be increased (**Chapter 1**). Next, we identify the data needed to support a new approach to agriculture and biodiversity (**Chapter 2**). Then we examine the short-comings of early approaches and present tools that are already available to expand agricultural production while managing the costs to the environment (**Chapter 3).** Finally, we identify gaps that a future MacArthur program could fill (**Chapter 4**) to assist in addressing the triple challenges of feeding the world, dealing with climate change and conserving ecosystem services and biodiversity.

Agriculture and biodiversity: the issues

Agriculture: a provisioning service

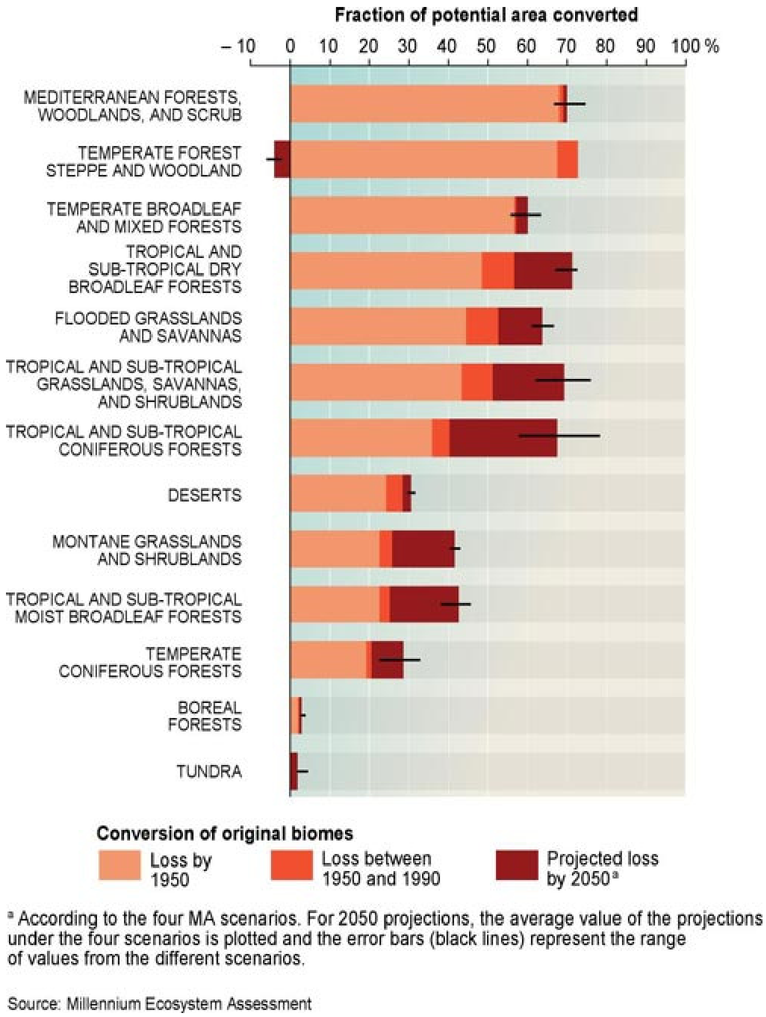
Agricultural production is vital to human well being and is a major provisioning service providing food fuel and fibres, as well as other human and environmental benefits. Agriculture generates agricultural or crop diversity and can be a driver of increased species richness, particularly in traditional grazing systems (Maxted 2003; Reid et al. 2004). In many areas, agriculture creates new ecosystems. Some of these do provide ecosystem services, although they are generally less diverse than the original ecosystems (Bauhaus et al. 2010).

Agriculture also drives development (World Bank 2008). It accounts for some 70% of rural employment and 40% of GDP in many developing countries. In industrialised countries, agriculture is economically much less important than manufacturing and service provision, but plays a pivotal role in landscape management. In the following sections, we review trends in land use change and evidence of the impacts of agriculture on biodiversity and ecosystem services and finally consider how agricultural production can be increased without further damage to the environment.

Trends in land use change and habitat loss

Agricultural lands including pasture now cover some 43% of the global land surface (Ramankutty et al. 2008), although figures vary depending on the definitions and methods used (Green et al. 2005). Cropland areas have expanded from some 3–4 million km^2 in 1700 to 15–18 million km^2 in 1990, mostly at the expense of forests. Likewise, grazing land has expanded from 5 million km^2 in 1700 to 31 million km^2 in 1990, mostly at the expense of natural grasslands (FAO 2003; Ramankutty et al. 2008). This growth in agricultural extent reflects the growth of human populations, from less than a one billion in 1700 to its current six billion. Much of this land conversion has occurred in recent decades. Since the 1980s,croplands have increased in Southeast Asia, parts of Asia (Bangladesh, Indus Valley, Middle East, Central Asia), in the Great Lakes region of eastern Africa, and in the Amazon Basin and Cerrado areas. Although, in the same period, declines in croplands have been recorded in the southeastern United States, eastern China, and parts of Brazil and in the former Soviet Union and in Europe (MEA 2005).

Assessments of habitat conversion indicate that temperate forests and woodlands suffered the most conversion up to the 1950s (Figure 1; MEA 2005). Since then, the majority of conversion has occurred in tropical forests and grasslands. Recent conversions have been associated with introduction of monocultures of oil palm, soybeans, and sugarcane for biodiesel and ethanol in the Brazilian Amazon and Cerrado, as well as oil palm in the Indonesian, Malaysian, and West/ Central African tropical forests (Klink and Macahado 2005; Fearnside 2001; Koh and Wilcove 2008). A sequence of maps of forest in Borneo illustrates the pace of conversion (Figure 2). One of the fastest expanding land-uses is for oil palm *Elaeis guineensis*. Its coverage has increased from 3.6 million ha in 1961 to 13.2 million ha in 2006, and is now equivalent to one tenth of the world's permanent cropland (FAO 2007)(Figure 3). Under future projections, habitat conversion is expected to be greatest in tropical forests, grasslands and in montane regions (Alkmade et al. 2010).



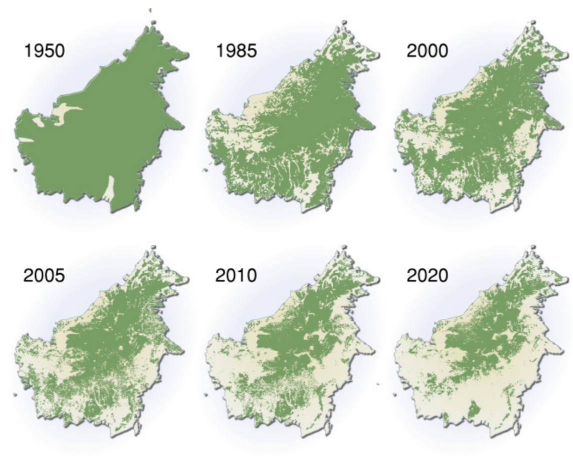


Figure 2.Extent of deforestation in Borneo 1950-2005, and projection towards 2020. Source: http://maps.grida.no/go/graphic/extent-of-deforestation-in-borneo-1950-2005-and-projection-towards-2020.

Figure 1. Extent of habitat conversion and projections of future change. Source MEA 2005.

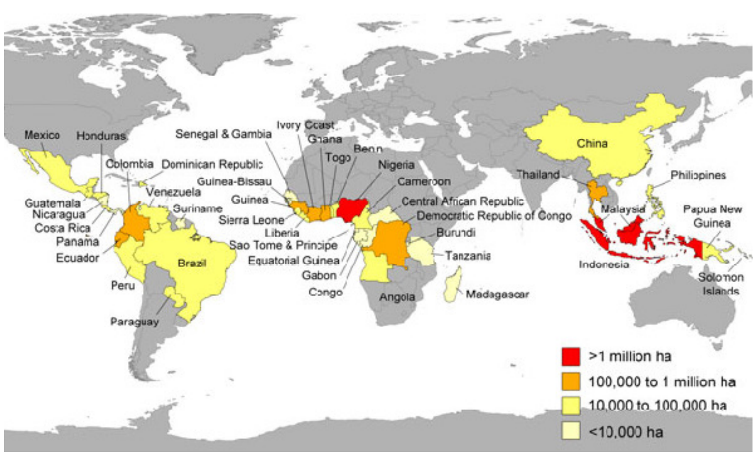


Figure 3. The area of oil palm growth in 43 countries. Source Koh &Wilcove 2008 (FAO data 2007).

How has agricultural expansion affected biodiversity?

Species loss

Agriculture mainly poses a threat to biodiversity through habitat loss when other ecosystems are converted for production of food, fuel and fibre. Pressure from agriculture is not measured directly for all species, but habitat loss as a whole is by far the most important cause of biodiversity loss. Some 60% of threatened vertebrate species are affected by it (Figure 4), including more than 40% of threatened birds (Figure 5). Recent assessments for reptiles and amphibians indicate that agriculture is a major threat to these groups too (Vie et al. 2008). In Europe, habitat loss, most often due to changing agricultural practices, is also the major threat to butterflies, beetles and dragonflies (IUCN News Release 16 March 2010).

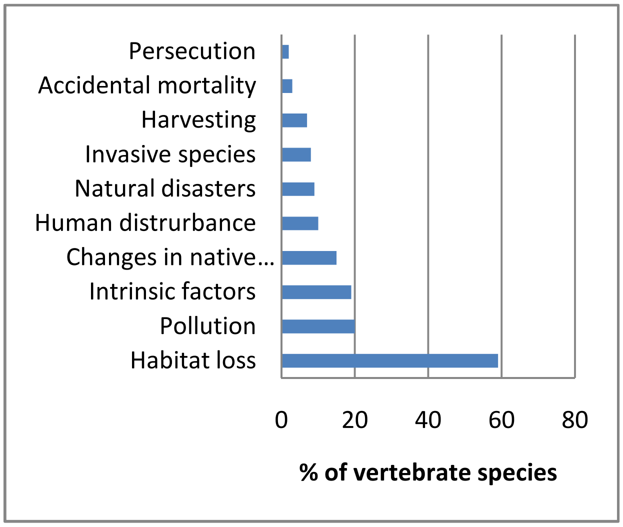


Figure 4. Percentage of vertebrate species affected by different categories of threat. Source: Vie et al. 2008.

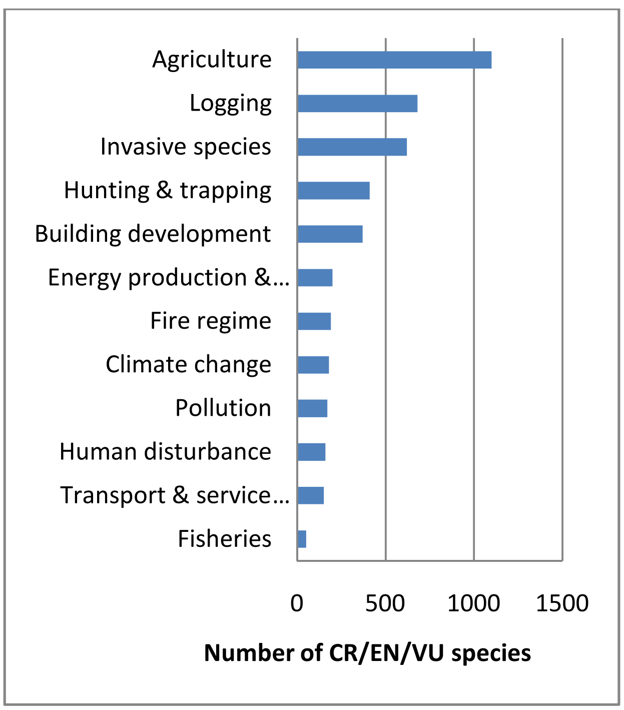


Figure 5. Numbers of different bird species affected by different threats. Source: Vie et al. 2008.

Apart from wholesale habitat loss, the intensification of farming has also affected biodiversity, including species that have adapted to farming practices. In the UK, a third of insects, four-fifths of farmland bird species and 90% of farmland weeds have declined (Robinson & Sutherland 2002). The decline in threatened farmland bird species has been directly associated with intensification of farming (BirdLife International 2008). Similarly, the greatest declines of birds associated with European farmland ecosystems have occurred in the more intensively farmed areas of north-western Europe (Donald 2001). In North America many bird species characteristic of farmland or grassland habitats have declined over recent decades (Peterjohn and Sauer 1999). Invertebrates too are affected and concern at the loss of agriculturally important functional species-groups such as pollinators and soil invertebrates has led to establishment of task forces on these groups under the CBD.

Crop wild relatives and crop races have also been diminishing. Despite sparse data, it seems that about 75% of the genetic diversity of agricultural crops has been lost since the beginning of this century (Maxted et al. 2007; FAO 1998). In China and Mexico only 10% and 20% of wheat and maize races remain (FAO 1998) and in German pastures about 50% of plant species have been lost (Isselstein et al. 2003). Yet these plants provide an invaluable reservoir of genetic material that may assist in adaptations to climate change (Maxted et al. 2007; Mortimore 2009).

The economic value of the ecological role of biodiversity and individual species is largely unquantified: valuation methods are sometimes controversial (Gahzoul 2005; Allsop et al. 2008; Whitfree et al. 2007). Some hint can be seen when functional groups are lost. For example in the deciduous fruit industry of South Africa, managed honey bees reportedly provide US$28.0–122.8 million worth of pollination services at a cost of only US$ 1.8 million (Allsop et al. 2008).

Land degradation - pollution

Agriculture is increasingly associated with loss of ecosystem services. Overuse of fertilizers, pesticides, water and tillage have all been associated with loss of soil fertility, soil erosion, and pollution of inland and estuarine waters through siltation and nutrient loading (MEA 2005).

The use of fertilizer and pesticides has been increasing in line with global food production since the 1960s (Figure 6) (Tilman et al. 2001). Overuse of fertilizers and pesticides can affect the environment either directly or through the export of pollution through run-off and the eutrophication of surface waters. Phosphorus transport into aquatic ecosystems is the principal cause of blue-green algae blooms in reservoirs, and the anoxia in the Gulf of Mexico is one example of eutrophication attributable to nutrient enrichment (Snyder 2001). Other harmful chemicals associated with agriculture include pesticides and veterinary drugs. Herbicides such as atrazine and glyphosate harm amphibians (Hayes et al. 2002; Relyea 2005), potentially contributing to global amphibian declines.

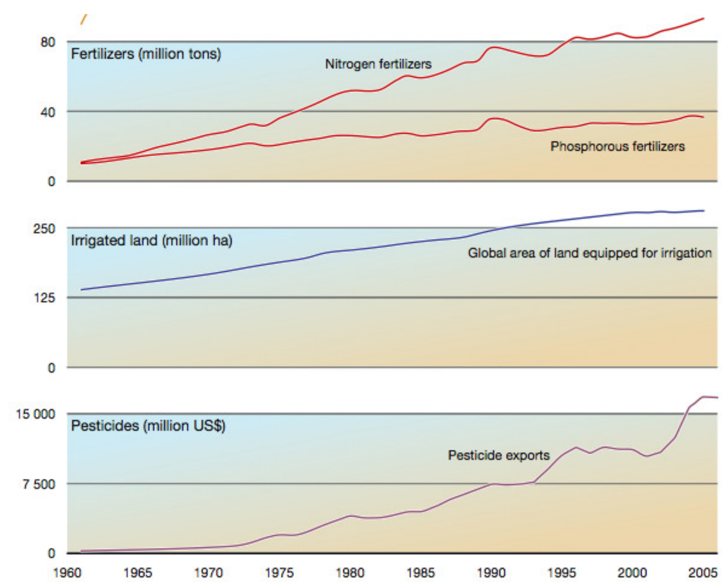


Figure 6. Global trends 1960-2005 in use of fertilizer, irrigation and pesticides. Source: from Nelleman et al. 2009.

Land degradation - soils

Soil degradation is estimated to have reduced global agricultural productivity by 13 percent in the last 50 years (Wood 2000); some 1964 million ha, 15% of agricultural land, are affected (Oldeman 1991). Over 40% of the degradation is in Asia, largely due to deforestation, agricultural mismanagement, and overgrazing. A further 25% of global soil degradation is in Africa, mainly because of overgrazing. Europe and South America each account for around 12% of the global total. In Europe, most soil degradation is due to bio-industrial activities and agriculture. In contrast the main problems in South America reportedly arose from deforestation.

Using changes in Net Primary Productivity (NPP) as a proxy for land degradation gives a different distribution of the problem (Bai et al. 2008, Figure 7). In either case, it is clear that land degradation is a serious problem in places: each year, 12 million hectares are lost to desertification (IFAD 2002).The situation in Africa is of particular concern. Some 950,00km^2 is threatened with irreversible degradation if nutrient depletion continues (Henao and Baanante 2006).

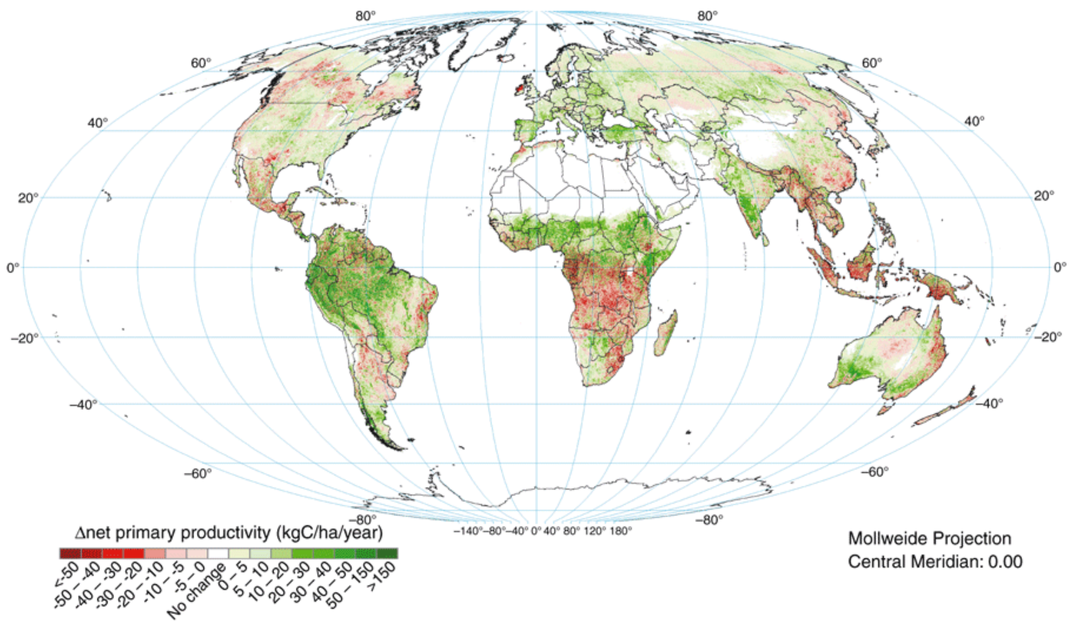


Figure 7. Global change in net primary productivity, 1981–2003 indicating degradation. Source Bai et al. 2008.

Land degradation- invasive species and biofuel crops

Many invasive species were introduced in an agricultural setting, either accidentally or purposefully, as bio-control agents or in some cases for production. The recent interest in biomass and biofuel crops has led to concern that some of the species proposed for development may become invasive (Global Invasive Species Database 2008; Buddenhagen at al 2009). For example, the giant reed *Arundo donax* is already invasive in parts of North and Central America, where it may increase the likelihood of wild-fires (Raghu et al. 2006). The African oil palm, *Elaeis guineensis*has reportedly become invasive in parts of Brazil where areas of threatened forest have lost their natural diversity (GISP 2008).Damage from invasive species costs over US $1.4 trillion annually or some 5% of the global economy, much of it due to those associated with agriculture.

How will agriculture meet future demand for food and fuel?

This section examines the reasons for expecting that agricultural demand will increase. It discusses some of the strategies that might be used to meet this demand and how they will impact on biodiversity and ecosystem services.

Increasing demand for agricultural products

The global population is expected to increase by 34% in the next 40 years, to 9 billion (FAO2010). At the same time, individual wealth is rising in many developing or transition countries and the middle class is expected to triple from 400 million in 2005 to 1.2 billion by 2030 (World Bank 2008). This growing human population, its increased buying power and growing demand for meat and animal products, suggests that food production will need to increase significantly, but it is still not clear by how much. Estimates of increases in food demand vary from a 40% increase by 2030 (FAO 2006) to a doubling in demand for meat alone by 2050 (Beintema et al. 2008). The most recent projection from FAO (2010) suggests that food production will need to increase by 70% by 2050 involving additional quantities of 1 billion tonnes of cereals and 2000 million tonnes of meat. As production of meat requires almost ten times the land area required to produce a similar amount of flour, large changes in dietary preference could have significant impacts on land-use (Gerbens - Leenes and Nonhebel 2002).

There is also increasing demand for biofuels to mitigate impacts of fossil fuel use on global warming, which will demand greater production of their feedstocks. Many countries are now adopting targets for renewable fuels of between 2-25% (see Table 1). OECD-FAO projections indicate that ethanol production will double and biodiesel production will quadruple by 2018. Taking these projections into account and considering that yield values for biofuel crops may have been optimistic indicates that the growth of agricultural production will need to be significantly greater than the 70% by 2050 needed for food alone (Johnstone 2009).

Table 1. Bioenergy targets for transport fuels in G8+5 countries

Country	Bioenergy targets
Brazil	Mandatory blend of 20–25 percent anhydrous ethanol with petrol; minimum blending of 3 percent biodiesel to diesel by July 2008 and 5 percent (B5) by end of 2010
Canada	5 percent renewable content in petrol by 2010 and 2 percent renewable content in diesel fuel by 2012
China	15 percent of transport energy needs through use of biofuels by 2020
France	5.75 percent by 2008, 10 percent by 2015 (V) 7 percent by 2010 10 percent by 2020 (M = EU target)
Germany	6.75 percent by 2010 set to rise to 8 percent by 2015 10 percent by 2020 (M = EU target)
India	Proposed blending mandates of 5–10 percent for ethanol and 20 percent for biodiesel
Italy	5.75 percent by 2010 (M) 10 percent by 2020 (M = EU target)
Japan	500 000 kilolitres as converted to crude oil by 2010 (V)
Mexico	Targets under consideration
Russian Federation	No targets
South Africa	Up to 8 percent by 2006 (V) (10 percent target under consideration)
United Kingdom	5 percent biofuels by 2010 (M) 10 percent by 2020 (M = EU target)
United States of America	36 billion by 2022 (M). Of this, 21 billion to be from advanced biofuels (of which 16 billion from cellulosic biofuels)
European Union	10 percent by 2020 (M proposed by EU Commission in January 2008)

1 M = mandatory; V = voluntary.

Sources: GBEP, 2007, updated with information from the United States Department of Agriculture (USDA, 2008a), the Renewable Fuels Association(RFA, 2008) and written communication from the EU Commission and Professor Ricardo Abramovay, University of São Paulo, Brazil. From FA0 2008.

Meeting increased demand for agricultural products

Future projections of agricultural production have been developed to consider how the challenge of increasing production can be met (MEA 2005, IAASTD 2008, FAO 2006, FAO 2009). Both the IAASTD (2008) and Royal Society (2009) reports concluded that a radical re-thinking of current agricultural practices will be needed. IAASTD favoured lower technology support to small holder farmers; the Royal Society emphasised a more technological approach (IAASTD 2008; Royal Society

2009). Taking these reports into account, in April 2010, a new 10 year research program was also developed for the Consultative Group on International Agricultural Research (CGIAR) that covered both low and high technology approaches (CGIAR) and so provides a useful focus for those interested in biodiversity conservation.

Approaches to increase production include i) improving crop yields per hectare; ii) increasing the area of land that is farmed; iii) increasing farming efficiency and reducing waste; or iv) a combination of these. The next section will consider the first three of these.

Improving crop yields

Some commentators, including the FAO, are optimistic that much of the growth in crop production can come from higher yields. This would be in line with past trends: cereal yield in Asia and developed nations increased by 60% from the 1960s to 1980s (Figure 8). However, this slowed to only a 30% increase between 1980 and 2000 (Wood 2000). Since then, yields have remained fairly stable, suggesting little remaining room for improvement (Figure 9). Furthermore, these gains have been at the expense of high inputs of fertilizers, pesticides and water. So, increasing yields without further impact to the environment in developed countries where agriculture is already intensified presents a major challenge for research and development (Royal Society2009; Deane 2010; FAO 2010).

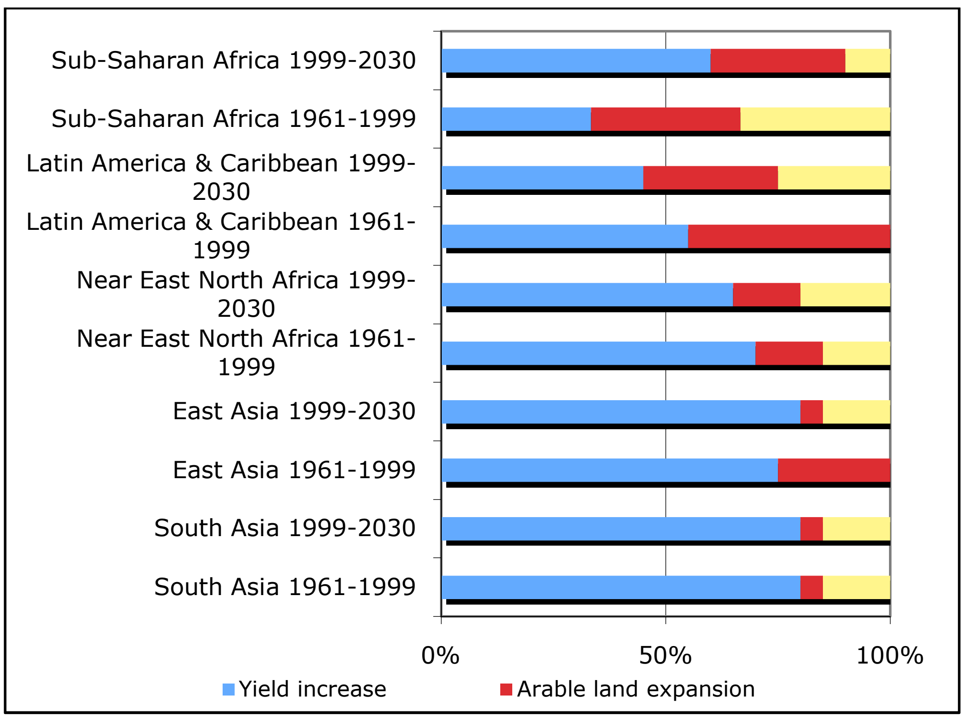


Figure 8. Sources of increased crop production 1961-1999 and 1999-2030. Source: FAO 2006.

Elsewhere, though, where less work has been done in the past, there is still likely to be room for improvement. In Africa, agriculturalists are optimistic that the yield gap, i.e. the gap between physiologically possible optimum yield and actual farm yield, can be improved. Here inputs of fertilizer, farming practices and crop breeding could all be improved (Fisher and Edmeades 2010). Plant breeding may help for both new fuel crops and also some staples used in developing countries, such as cassava, that have seen less interest from plant breeders. However, plant breeding and other options requiring further research entail a 10 to 15 year lag in producing tangible improvements in farming outputs (Royal Society 2009). Nonetheless, the African Agricultural Technology Foundation is already working to forge public-private partnerships for access to proprietary agricultural technologies. For example, it is currently distributing Strigaway©Maize that has been developed with tolerance to the herbicides used to fight the Striga parasite (http://www.aatf-africa.org/). As striga can reduce maize outputs by 40-80%, this could make a big contribution to African maize production.

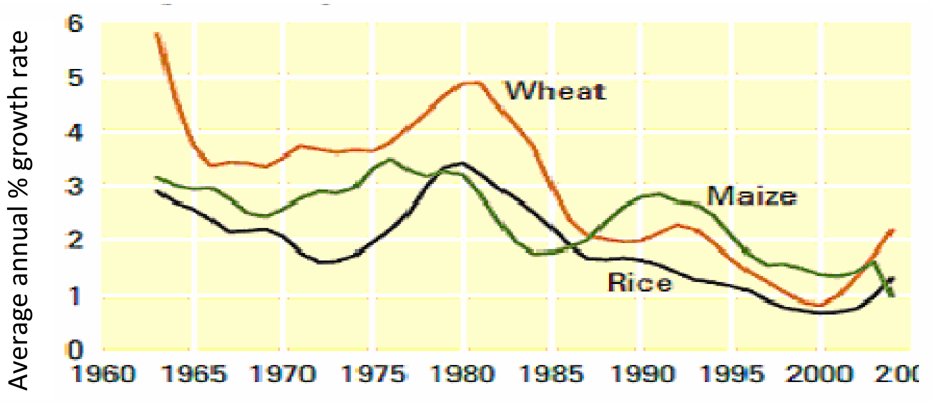


Figure 9. Average annual % growth rate of production for major cereal crops. Source: World Bank 2008

The problem of water supply

Even if plant breeding can bring appreciable gains, water may still be a limiting factor to agricultural production. Greatly increased use of water has contributed to the large global gain in cereal production achieved since the 1960s. Abstraction for agricultural purposes now accounts for some 70% of global water use (FAO Global Perspective Studies Unit 2007). Now, however, water is already in short supply in many regions, and a 34% increase in the global human population will further strain water supplies, even without added agricultural requirements. Nevertheless, water availability varies regionally and some studies suggest that water would be available to develop further irrigation potential in East Asia, South Asia and Latin America and the Caribbean (Bruinsma 2009).

Genetically modified organisms

Genetically modified organisms (GMOs) are seen by some as holding the key to increased production, but this is controversial. To date GM crops have largely been developed for herbicide tolerance and pest resistance, particularly in the US, where GM plants accounted for some 80 % of soybean, corn, and cotton acreage in 2009. The most recent comprehensive study of GM crops concludes that they provide net environmental and economic benefits, but that these are not universal (NRC 2010). However, to date, GM crops have only increased production by around 0.3-0.4% in the US (Fischer 2008) and there is the risk that weeds develop herbicide resistance, limiting the benefits of GM crops (Nueman and Pollack 2010; Bagla 2010). An FAO symposium on 'how to feed the world' concluded that GMOs are far from a panacea for food security (FAO 2010).

Land sparing

In theory, intensification of farming could spare land for biodiversity. As crop productivity per unit of land is increased, less land will be required to supply a given level of harvest (see Ewers et al. 2009; Green et al. 2005; Scherr and McNeeley 2008). This idea is supported by the observation that global agricultural output has increased by 140% since the 1960s for only an 11% increase in cropland area (FAO 2006; Royal Society 2009). In addition, countries with higher agricultural yields have lower deforestation rates (Barbier and Burgess 1997). Some studies show reduced expansion of agricultural areas as crop yield increases (Southgate 1994; Ewers et al. 2009). But, simply increasing yield may not necessarily reduce deforestation, if farmers are responding to market opportunities. Local deforestation rates have been shown to increase in line with increases in commodity prices (Gaveau et al. 2009). Whilst in Africa, Asia and Latin America between 2000-2005 forest loss has increased as both the urban population and exports of agricultural products have grown (De Fries et al. 2010). The value of adopting land-sparing approaches will need to be assessed on a case by case basis.

Increasing the amount of farmed land

If crop yields cannot be increased sufficiently to meet the demand, will more land be converted to agriculture? Some 80% of the past increases in crop output have been delivered with relatively little expansion in the area of cropland. Agriculturalists have tended to assume that this pattern will continue, but as discussed above, it may be hard to repeat past yield improvements. Deriving even 20% of the necessary production increase from expansion of arable land is projected to require 5% more land globally - an expansion of 120 million ha in developing countries, or 20% of their land area, although in developed countries a contraction of some 50 million ha is expected (FAO 2010).

If much more land is needed for agriculture, suitable land is reportedly available in several regions, with some 800 million ha in each of Latin America and sub-Saharan Africa (FAO 2006). But many assessments of land availability fail to take account of carbon stocks in forest and soils, or of land set aside for biodiversity conservation. When these issues are factored in, calculations suggest that underutilized land that is suitable for agriculture is in relatively short supply (Young 1999). Nevertheless, there is already renewed land clearance in the Amazon and Congo forests and Indonesia, for growth of oil palm and other biofuel crops and associated with so-called “land-grabs” (Cotula et al. 2009).

Farming efficiencies and harvest losses

If yield improvements and the availability of land for conversion are uncertain, what other options are available? Studies suggest that improvements in current farming and distribution practices could help to increase efficiency and reduce wastage. Wastage of current agricultural production can be very high, and may account for around one third of cereal production and up to 50% of fruit and vegetables in some areas (Kantor et al. 1999; Henningsson 2004). Pre-and post harvest losses in developing countries, where little pesticide or herbicide is used, can account for 20-40% of the potential harvest due to pests and pathogens (Kader 2005). Clearly, there is room for improvement.

In addition, some 20% of current cereal production is used as animal feed. If cereal feeds were not used for livestock rough calculations suggest that by 2050 1.4 million tonnes a year could instead supply the calorie needs of 3.5 billion people annually (Nellemann et al. 2009). But some meat production benefits biodiversity. In many grassland ecosystems, plant diversity is maintained through grazing. Indeed, in many regions diversification and mixed farming is being encouraged as a means of recycling nutrients and improving human diets (Erenstein and Thorpe 2009).

Other issues that may affect food production

Governance of land

The importance of governance issues to the sustainable development agenda is widely recognized (World Bank 2008; Cotula et al. 2009). In many agricultural areas, governance and tenure remain uncertain and weak (Zimmermann 2004). Without secure rights to land, responsibility for the long-term and sustainable management of land is likely to be lacking. This adds to uncertainty over food supplies, not least because improved equity over land has been associated with increased productivity (Hussain 2005). One current issue is transnational land-leasing and purchase schemes, which are likely to affect the rural poor who do not have secure land rights. This lack of rights, coupled with the liberalization of world trade, has led to the growing strength of a food sovereignty movement, which seeks to assert the rights of local people over food resources and decision-making. At the most recent World Food Summit this group became very prominent (IISD 2008/9). Experience in Europe has shown that secure land ownership is not a sufficient condition to deliver biodiversity conservation. But as governance and land tenure issues are important to both the food production (FAO 2009) and biodiversity conservation (CBD Addis Principles) sectors they provide a focus for collaboration and will often be central to efforts to build ecosystem resilience.

Climate change

Climate change will affect agricultural productivity in different ways through carbon dioxide fertilization, increasing temperatures and changes in rainfall patterns. Furthermore, these effects will differ regionally and their impact will depend on a range of factors including crop characteristics (IPCC 2007). However, the availability and suitability of productive agricultural land, especially for rain-fed for crop growth, is likely to change significantly over time. In terms of agricultural suitability, temperate lands are expected to become more productive while farmlands in the tropics are expected to be drier, or more prone to unpredictable temperature spikes, and unpredictable events such as floods and droughts. In turn, it is also possible that large-scale changes in land-use could feed-back and exacerbate climate change. For example, large-scale deforestation and replacement with crops are expected to affect global water balances as forests are responsible for much water capture and recycling through transpiration. All of these uncertainties make it difficult to construct credible models and scenarios about the relationship between crop productivity and the need to find new agricultural lands.

Agriculture is also a major source of the greenhouse gases that contribute to climate change. Carbon is emitted when lands are cleared for agriculture and it is estimated that land-use change, primarily deforestation, is responsible for as much as 18% of global GHG emissions (IPCC 2007; MEA 2005). In some areas, soils too hold significant amounts of carbon, and degradation of the soil carbon reservoir through poor agricultural techniques can emit carbon. Agriculture also emits significant quantities of carbon through the use of fossil fuels to produce fertilizers and pesticides, as well as for farm machinery. In all, estimates suggest that agriculture is currently responsible for some 30% of green house gas emissions (Trumper et al. 2009).

Projections of further species loss

Projections of land use change vary significantly, so predicting the impacts on biodiversity is challenging. The consortium that produces the GLOBIO biodiversity model has mapped predictions of change in terms of variation in a biodiversity index of mean species abundance (MSA) in relation to one of the scenarios of the Millennium Ecosystem Assessment (MEA 2005). Their results predict further significant impacts to biodiversity in India, sub-Saharan Africa, Indo-China and parts of South East Asia (Figure 10).

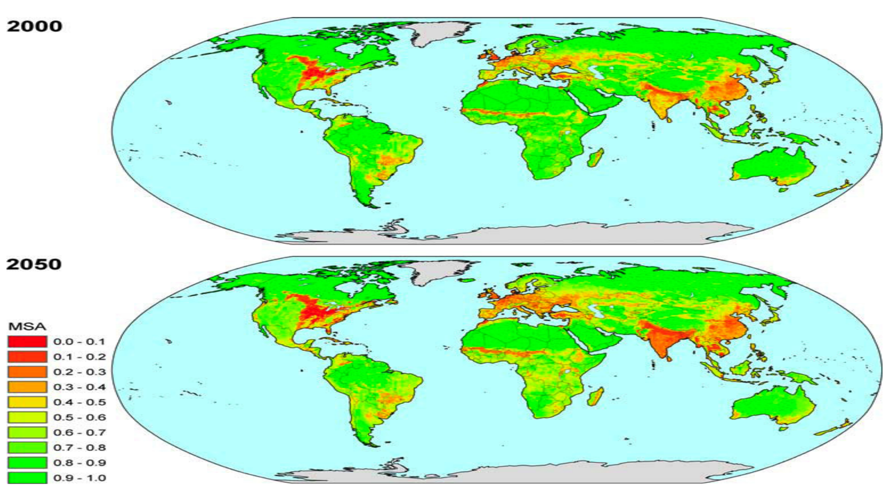


Figure 10. Combined relative mean species abundance of original species (MSA), using all pressure factors, in the year 2000, and in the reference scenario for 2050 (Alkemade et al. 2009).

Section summary

This section has shown that agriculture, and agricultural expansion, are vital for human well-being, but are also the major driver of biodiversity loss from the local to the global scale. From a human perspective, agricultural production not only contributes to food security, but generates employment and contributes significantly to GDP in many countries. Some kinds of agriculture can maintain important biodiversity, but the conversion of some 43% of the planet's terrestrial land surface, coupled with intensive farming practices has resulted in huge impacts on biodiversity and serious damage to vital ecosystem services through the loss of soil fertility, pollinators and pest predators, as well as the pollution of water courses and overuse of water resources.

The projected 34% increase in the human population brings even greater challenges. Agricultural output for food will have to increase by over 70%. In the past, increases in cereal outputs of more than 100% were achieved with a relatively small increase in cultivated area, but relied on high levels of artificial inputs. All the evidence on hand suggests that it is naive to believe that yields will increase to a similar degree over the next 40 years. There is also considerable uncertainty and variability in the information and tools used to project the future. In the meantime, the conversion of land continues. So, what can be done to reduce the likelihood of further losses of biodiversity and ecosystem services and raise the issue up the policy agenda?

2. Strengthening the evidence-base

If we are to stimulate policies that recognize the importance of biodiversity, give it equal importance to agriculture and incorporate it fully into landscape management, the value of biodiversity will need better recognition. The threat of further agricultural expansion has yet to be taken seriously (Foley 2010). So we need to make the case for biodiversity much more strongly. To fully value biodiversity and ecosystem services, we will also need ways of measuring and apportioning the costs and benefits of maintaining ecosystem services (TEEB 2009). Further land conversion may be inevitable, but good knowledge and use of a precautionary approach should help to minimize conversion and avoid the higher costs of possible restoration at a later date (Cooney and Dickson 2005).

An early requirement is for better models of agricultural change. Projections of how agriculture might expand and intensify require critical evaluation to assess the assumptions underpinning the models and the likely impacts of that expansion (Sutherland et al. 2009). Currently, almost nothing is known about probabilities of different outcomes associated with models and projections. For example, FAO (2010) states that land conversion is expected to be in the region of 5% of total land cover over the next forty years – but there is no indication of the confidence in this estimate. Meanwhile, predictions of the impacts on biodiversity depend on outcomes from the IMAGE model of land-use change which in turn depends on outcomes from the world food system models of IFPRI and FAO/ IIASA (Alkemade et al. 2009; Alcamo et al. 2005; FAO 2009;Rosegrant et al. 2009). Errors or inconsistencies in any of the earlier models will have important consequences for our understanding of biodiversity outcomes.

If further land conversion is inevitable we, as a society, need to plan for that change and negotiate trade-offs that meet the needs of biodiversity conservation. To do so, we need to be well informed about past practice and also to have good information about current distribution of biodiversity and about the potential of land for different uses at national and site levels. Projections of future impacts at the national level are vital. These are possible now that further information is available on likely demand for agricultural and biofuel production. Techniques such as integrated conservation planning, landscape design and eco-agricultural approaches will all have roles to play in minimizing the impacts of land conversion at the site-level (Knight and Cowling 2010; Pretty, 2008; Scherr and McNeely 2008). New approaches will also be needed to incentivise sustainable land management, production and consumption (TEEB, 2009). These approaches may include payments for services as well as regulation of damaging activities. To respond efficiently to these incentives, new and alternative techniques, such as precision agriculture, crop diversification and conservation agriculture in intensively and extensively farmed areas, will require wider adoption (Swinton and Lowenburg-Deboer 2001; Brusaard et al. In press). Given the close association between ecosystems, agricultural production, livelihoods, and consumption, multidisciplinary work and integrated decision-making will be particularly important.

Integrated data collection

To help negotiate trade-offs in future agricultural policy and land-use decisions, the biodiversity community will need robust arguments, and lessons from past experience supported by good data. Indeed, recent global syntheses on both agriculture and the environment have called for better data at the local and national level to inform local decisions and implementation (MEA 2005, IAASTD 2008, TEEB 2009). Local level data for agricultural decision-making will include information on very local conditions, such as soil fertility, slope and microclimate to assess production potential. Production output statistics and data on agricultural areas are also needed to predict future global demand and production levels, but there is a need for a massive improvement in the gathering of all this information (FAO 2009). Similarly, biodiversity and land cover data could be greatly improved: our understanding of biodiversity, its role in ecosystem resilience, and its distribution is still fairly superficial (Orians and Groom 2006). There are now broad distribution maps for many vertebrate species, but much less is known about species of agricultural significance, such as invertebrates, fungi and crop wild relatives (Maxted 2003). Information on the economic and social value of land is poor in many countries. Better data are needed on the relative values of land for agricultural production and for the maintenance of ecosystem services and biodiversity. All this information will be vital to balance trade-offs between different land-use options and include stakeholders in developing systematic conservation plans as competition for land and other resources increases (Knight et al. 2008).

Establishing the necessary data collection, storage and retrieval systems will require better integration between the agricultural and biodiversity sectors. FAO and its partners are already building capacity in Africa for remote sensing and the collection of crop data. Alongside this, greater capacity is needed in the environment sector to ensure the mainstreaming of biodiversity and ecosystem service considerations into land use planning decisions. FAO and other capacity building projects may provide an opportunity for partnerships to simultaneously build agricultural data, biodiversity assessment and monitoring capacity. With specialists from both sectors working collaboratively on data collection and integration, the resulting combination of agriculture and biodiversity data would allow planners and stakeholders to identify areas of greatest need and potential for sustainable rural development. The biodiversity and development agenda are already being integrated through poverty and conservation linkages, so adding agriculture will help to focus planners on areas most in need of intervention. These issues are explored in the case study of the Democratic Republic of Congo on page 21.

Important geographic areas for focused data collection:

The largest areas of as yet unconverted land suitable for agriculture are to be found in sub-Saharan Africa and Latin America (Figure 11) (FAO 2010). There has already been great interest in the potential of these lands, particularly those close to water and market infrastructures, and 15- 20 million ha have been subject to negotiations involving foreign investors since 2006 (Royal Society 2009). Countries that have been targeted include Brazil, Cameroon, the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Sudan, The United Republic of Tanzania and Zambia.

Examining preliminary data on land suitability for commodity crops suggests that areas in Central Latin America, West/ Central Africa and South East Asia are suitable for soybean, oil palm and sugar cane expansion (Miles et al. 2008). On the whole, Brazil, Democratic Republic of Congo, Indonesia, Peru and Colombia have the largest land area suitable for this combination of crops (Stickler et al. 2007). An overlay of protected areas indicates that the greatest potential overlap and conflict occurs in the southern parts of Amazonia and in South East Asia. In the Congo region there is relatively little overlap between protected areas (PAs) and crop potential, largely because only a small proportion of the landscape is actually protected. But, agricultural interest in the Congo Basin suggests that future rates of deforestation in this area may be high. In the Brazilian Amazon around one third of land suitable for agriculture is unprotected, and another third is under some form of private ownership, although land title is often unclear (Nepstad et al. 2007).

Given its poor food security, Africa is already a major focus for agricultural improvement as its population is expected to double by 2050(UNDP 2006; Royal Society 2009). The continent suffers from land degradation, with some 95 million ha of land where yield is reduced by 2-40% (Henao and Baanante 2006). In parts of West Africa, the soils have an inherently low carbon storage capability, which limits both water retention and agricultural production (Bationo 2007). Furthermore, Africa is projected to lose some 9% of its agricultural areas due to climate change by 2080, and agricultural output may be reduced by 60% for a few countries and between 16-27% for many others (Fischer 2002; Lobell 2008; De Schutter 2009). More positively for food provision, many parts of Africa are thought to have sufficient water to support a significant expansion of irrigated farming, providing that storage facilities can be developed (Markwei 2008). Equally, the UN Special Rapporteur has also noted that around half the land in sub-Saharan Africa is arid or semi-arid and has cautioned against overlooking the rights and needs of pastoralists/ agro-pastoralists, whose agricultural activities are often relatively conservation friendly (De Schutter 2009). It is already clear that unless agriculture and conservation interests are integrated to generate mutual benefits and trade-offs, a resurgent interest in agriculture will pose a huge new threat to Africa's unique biodiversity and ecosystem services.

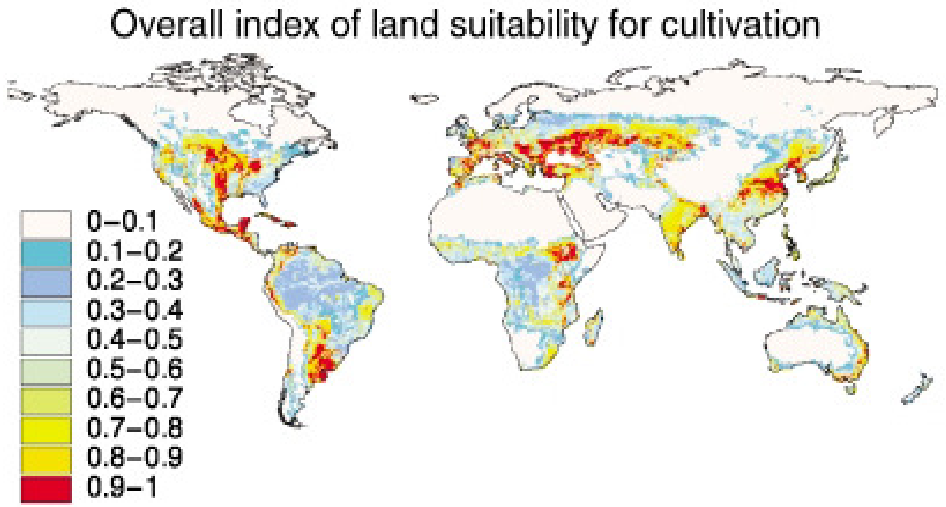


Figure 11. Overall index of land suitability for cultivation. Source: Ramankutty 2002.

In Asia, agriculture is likely to be affected by sea level rise in the mega deltas (IPCC 2007). Rice is particularly vulnerable to high temperatures and this, compounded by the potential loss of dry season meltwater from the Himalayas could have major impacts on agriculture (IPCC 2007; Xu 2009). However, parts of South East Asia are amongst the most productive in terms of crop outputs, so crop growth in other areas may be possible. But, these highly productive areas also support important forests and peat soils that contribute to carbon sequestration strategies and support unique and charismatic biodiversity which would be under threat if agriculture expands further (Figure 12).

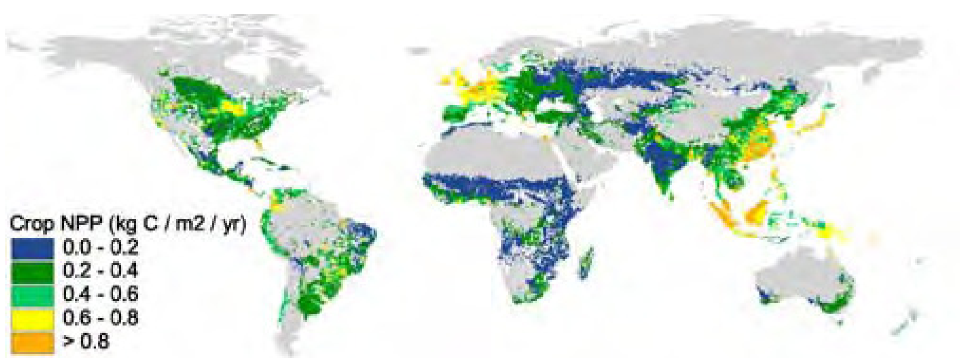


Figure 12. Distribution of crop Net Primary Production (NPP). NPP of croplands calculated by transforming the yield of each crop into NPP and then performing an area-weighted average of the NPP of all crops in each grid cell. Source: Monfreda et al 2008.

Taking an ecosystem view, modeling studies indicate that grasslands and savannas will be particularly vulnerable to conversion over the next 40 years. In Latin America, the Cerrado areas of Brazil have already been heavily impacted by the introduction of arable agricultural systems and the high altitude grasslands of the Andes are under impact from local farmers, while in Africa, the Maasai Steppe is subject to increasing cultivation. These grasslands and savannahs are considered further in the Kenya case study on page 29.

Case Study 1. Integrated data for decision-makers in the Democratic Republic of the Congo

Introduction

Sub-Saharan Africa is a major target for agricultural expansion to meet its pressing needs for food security and development (FAO 2010). This region has high levels of biodiversity and large standing stocks of carbon in its forests (Hilton Taylor et al. 2004; Scharlemann et al. 2009). Unregulated forest conversion to agricultural land would have far reaching effects on both global and local carbon budgets and contribute to climate change (IPCC 2007). Such conversion could also affect biodiversity conservation and delivery of ecosystem services. Moreover rural people may lose access to traditional lands and be forced to convert other areas of forest (Cotula et al. 2009). This case study investigates how integrating and mapping environmental, social and agricultural data could facilitate efficient land-use planning to deliver human and environmental goods and services for the long-term.

Challenges facing the Democratic Republic of Congo

The Democratic Republic of Congo (DRC) exemplifies some of the challenges faced by Africa as a whole. It is particularly rich in biodiversity: it supports more species of birds and mammals than any other country in Africa (WRI 2004) and encompasses a major centre of plant diversity where endemism and species diversity is particularly high. As part of the Albertine Rift hotspot, DRC contains much of the remaining mountain gorilla habitat in the Virunga Mountains. It also has the largest area of forest of any African country: 1.1 million sq km of dense humid tropical forest, which retains around 17 billion tons of carbon a significant portion of global tropical forest carbon (WHRC, 2007). Around 11% of these forests are nominally conserved in protected areas.

In the past, mining, logging and refugees from conflict have been key drivers of deforestation and biodiversity loss. Recently, oil palm cultivation for biofuels has become an important driver because DRC's dense humid forest area is perfect for oil palm cultivation in terms of both soils and climatic conditions (WHRC, 2007; Miles at al 2008). In 2007 there were reports of Chinese interests buying millions of hectares of land and of Malaysia's minister urging palm-oil businesses to look to DRC for future land and business opportunities. The DRC President has reportedly offered to lease 10 million hectares of agricultural land to South Africa (Cotula et al. 2009).

The country has a relatively low population density of around 22 people per km^2 compared with a world average of 45 people per km^2 (WRI, Earth trends 2003). However, the GDP per capita is one of the lowest in the world at US$300 in 2008, and 76% of the population is listed "chronically hungry" (IFPRI 2009). Investments in agriculture have been low and people live almost exclusively on a diet of cassava flour, which is low in nutritional value. Health experts recommend adults eat 2,100 kilocalories a day for a healthy diet but the average intake in the DRC is 1,650 a day (IFPRI 2009). Decades of war and under-investment have meant that agricultural infrastructure is lacking and a poor road system makes it hard for people to reach food and markets.

Making trade-offs in land-use

Given all these pressures, policy-makers in countries such as the DRC have to consider how to make informed trade-offs between different types of land-use. Potentially competing choices include food production, carbon conservation (and with it the potential of earning income through schemes for Reducing Emissions from Deforestation and Forest Degradation REDD), export earnings, rural livelihoods and biodiversity conservation. Such trade-offs can be affected by changes in the macro-economic climate, such as the increasing price of oil in 2008/9 or the recent global economic downturn. Policy-makers, business leaders and landowners need information that allows them to determine which areas are most suitable for different uses.

Information needs

Ideally, national level decisions on land-use planning should be supported by reliable information on a combination of ecological, agricultural, social and economic factors. High quality maps integrating such information at an appropriate spatial resolution are particularly valuable. Here we present what information is available on land-use change, ecosystem services, biodiversity and suitability for agriculture and outline necessary improvements.

Land-use change. There are global land cover maps and assessments using both remote sensing and site-based surveys. For example, there are maps of historic landcover change (Goldewijk and Ramankutty 2004) and forest assessments (http://www.fao.org/forestry/fra/fra2010-remotesensing/en/). Maps of land cover in 2000 (GLC 2000) and of crop and agricultural production area in 2000 (JRC 2003; Monfreda et al. 2008) have been produced.

Ecosystem services. Mapping is proceeding rapidly. Water and carbon maps are common (see IMWI http://www.iwmi.cgiar.org/WAtlas/default.aspx; Scharlemann et al. 2009) and there has been an attempt to map natural grassland contributions to livestock production (Naidoo et al. 2008). Global soil maps are being produced (http://www.globalsoilmap.net/)

Biodiversity. There has also been rapid progress in mapping global biodiversity. A wide range of biodiversity priority sites has been identified, such as Protected Areas, Key Biodiversity Areas, Endemic Bird Areas, Biodiversity Hotspots and Global Ecoregions, to name a few (Murdoch 2010). Distribution maps are also being developed for species assessed in the IUCN Red List of Threatened Species, and the distribution of all bird species should be updated by the end of 2010.

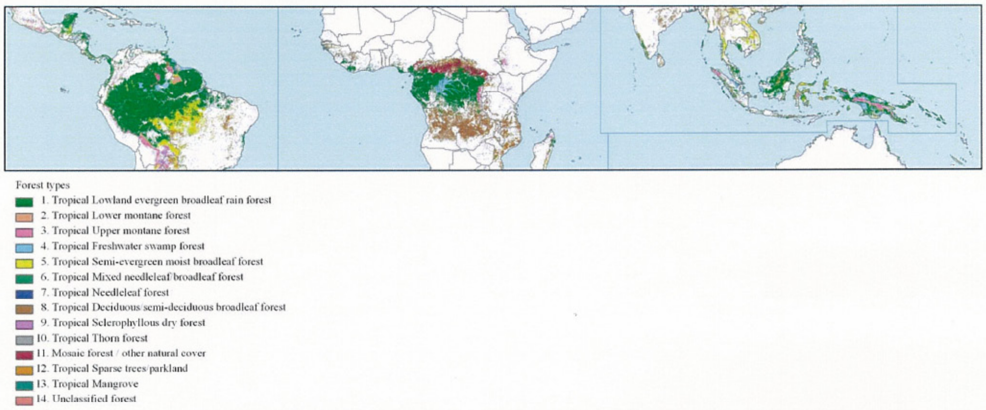
Suitability for agriculture. WCMC has recently produced tropical maps of suitability for different commodity crops in conjunction with maps of forest coverage, which highlight areas of potential conflict (see Figure 13) (Miles et al. 2008).

These global maps demonstrate the potential of land in the DRC, but the data is not at sufficient resolution to be used meaningfully at the national level. There is some national information on agricultural output through the FAO statistical services (FAOSTAT), but it is constrained by national reporting which can be very patchy. FAO has recently launched CountrySTAT, a program to help national governments to collect and maintain relevant data on agriculture, and that harmonises data on agriculture and food production from different sources. Reportedly countries that have adopted/embraced the new system of data management include Ethiopia, Ghana, Malawi, Mozambique, Tanzania, Nigeria, Uganda and Zambia. FAO's Africover project too has been building national remote sensing capacity and has resulted in maps of national forest cover, and extent of agriculture (Figure 14).

Proposed future work

Support for systematic national land-use planning is needed to help countries such as DRC address their development options, food security challenges, responses to climate change and to the conservation of their biodiversity. This support will include not only data collection, collation and display, but also the development of means to compare the values of different options. It should also help to identify areas that are essential for food production, carbon sequestration, timber extraction and biodiversity. Policy-makers can then determine how to manage these areas, and how management costs will be supported.

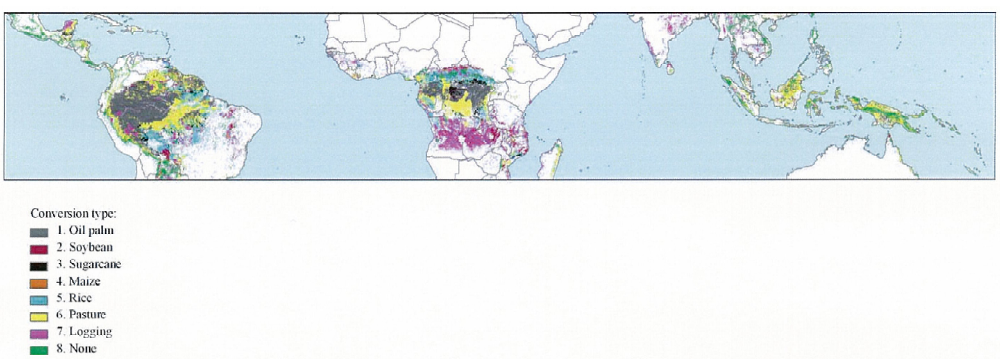
The MacArthur Foundation would be well placed to develop partnerships with Foundations supporting capacity building and data collection for agricultural planning, by supporting similar activities for biodiversity and payments for ecosystem services. A pilot project to show what can be done and how data can be used to assist planning at the national level would be an important and appropriate first step.



Map 1: Tropical forest coverage and types from 2008 revision of Global Forest Map, showing region boundaries used for analysis (Latin America, Africa, Asia and Australia/Oceania[1]).

[1]Hawaii is omitted from the map extent, and bundled with Australia for summary statistics

Map 2: Carbon stock density in tropical forest (above and below ground biomass plus soil carbon)



Map 12: Most valuable suitable land use for tropical forest area

Figure 13. Maps developed by UNEP-WCMC for The Eliasch Review, which show 1. The distribution of forest in the tropics; 2. The distribution of carbon stock density; and 3. The most valuable alternative suitable land uses (Miles et al. 2008).

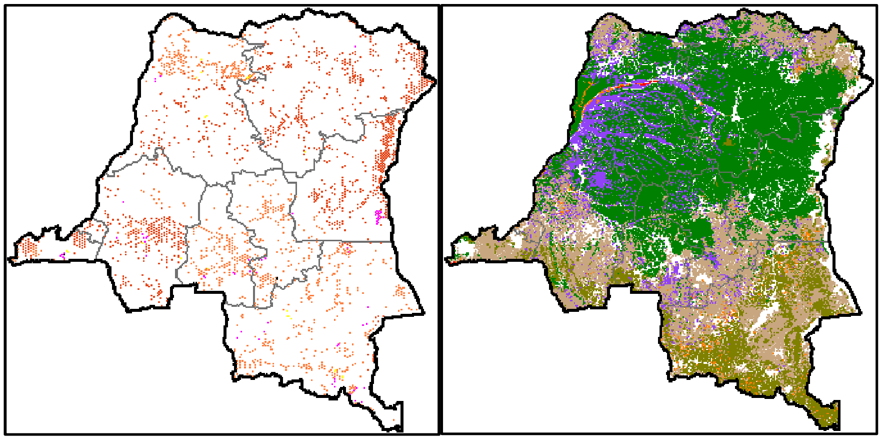


Figure 14 Map of DRC showing I) area under agriculture and ii) area covered by forest and woodlands. Source FAO Africover.

Section summary

This section has examined the evidence base needed to inform decision-makers about the value of different land use options. As the world population grows and demands for agricultural products increase, increasing trade-offs will be required between different land uses. Natural ecosystems are likely to be increasingly converted for agricultural purposes, particularly in areas of Latin America, Sub Saharan Africa and parts of Asia. Grassland ecosystems are likely to be most at risk, particularly if REDD provisions help to safeguard forests.

We will need realistic assessments of our ability to increase agricultural output in different regions, taking account of water shortages, distribution constraints and production inefficiencies and time-lags for crop-breeding improvements. Decision-makers will require better information on land potential for different uses at the local and national levels to guide land-use planning.

3. Approaches and tools to encourage sustainable land use

We have seen that past agricultural practice has damaged biodiversity and ecosystem services and that even greater agricultural production will be needed to meet human needs in the decades ahead. The challenge is to plan for increased agricultural outputs and negotiate trade-offs that also ensure the maintenance of biodiversity and ecosystem services. In doing so, we have to first consider why we have not been more successful at addressing the impacts from agriculture over the past 40 years, then consider what tools are available. This chapter considers conservation approaches to date and then the future approaches to meeting that challenge.

Conservation approaches over the past 40 years

Traditionally, conservation and agriculture have been separate sectors, managed by professionals with their own disciplinary training and views, often in conflict with one another. Protected areas were historically established in areas that were marginal for agriculture (Leader-Williams et al. 1995). For the strict conservationist, the "best" protected areas were seen as those that were wilderness areas in which there was no use (Terborgh 2004). Inevitably this approach resulted in separation of land use into areas for agriculture and those for wilderness. Meanwhile, following the devastation of the second-world war in Europe and the early World Food Summits, the focus of global, regional and national agriculture bodies was to increase production to feed a hungry world. Government policies provided subsidies to encourage agricultural production, when there was little understanding of the environmental costs. Battling against forest loss and species extinction, the emerging field of conservation tended to focus on the hard-won protected areas. This began to change with adoption of the Convention on Biological Diversity, with its three pillars of conservation of biological diversity, sustainable use of biodiversity and access and benefit sharing. But even in the Convention, agricultural biodiversity has been addressed in a distinct Program of Work, which has inadvertently continued the separation between agriculture and biodiversity conservation. Now that there is increasing evidence of shifts in species range due to climate change and of the importance of ecosystem services and the role of biodiversity, these separatist strategies need re-thinking and conservation strategies need to address management of the whole landscape. Initiatives such as the Satoyama Initiative and the GIAHS concept as well as Community Conserved Areas, which will be discussed in a later section present promising opportunities for greater integration.

Tools to encourage sustainable land use

Ecosystem approach, landscape planning and connectivity conservation

Traditionally, conservation and agricultural areas have been separated by sharp edges. But there is growing recognition of the value of a landscape approach that seeks to integrate different land-uses within a matrix (Scherr and McNeely 2008). For example, in Australia, the federal government has promoted a landscape that supports threatened biodiversity by covenanting areas for conservation within farmland (Caring for our Country 2010). Similarly, in Russia the conservation of cranes has included the purchase of farmland for a reserve and development of a demonstration farm to spread good farming techniques (Pryde 1999). Connectivity conservation approaches, whereby large areas are managed to provide linkages between protected areas and ecosystems, are increasingly common in mountain regions and could be adapted to lowland areas (Warboys et al. 2010). Specific tools that can aid implementation of these landscape design approaches at the site level include alternative-futures analysis whereby communities consider the outcomes of different scenarios of future land use change (USEPA 2002); landscape species approaches whereby maps of species landscape needs are compared with human impacts on the landscape to identify future action (Sanderson et al 2002), landscape design and conservation planning whereby stakeholders are involved in developing local land-use trade-offs (Knight and Cowling 2010).

Sustainable Agriculture and Rural Development

Consideration of poverty alleviation, food security and high prices of external inputs such as oil has led to renewed interest in more sustainable agricultural techniques (Godfray 2010). This provides an opportunity to include environmental considerations into agriculture planning for the coming decades. In developing countries, a major portion of food supplies are produced by rural smallholder farmers (IAASTD 2008). By working with these smallholders, agricultural extension workers and conservationists could have an important impact on sustainability of farming systems (Pretty 2008; Scherr and McNeeley 2008). Tropical soils in some areas have low levels of fertility, and the increasing price of inorganic fertilizers puts them beyond the reach of many farmers. Consequently low cost farming techniques such as inter-cropping with legumes, zero tillage, integrated pest management and agroforestry are re-emerging and provide an opportunity for improving biodiversity conservation as well as increasing productivity (ICRAF 2009). The use of low technology inputs has improved yields dramatically in areas where soils had become impoverished and overused (Li et al. 2007). By incorporating information on biodiversity and ecosystem services into guides that the FAO and others are developing, and by disseminating techniques such as conservation agriculture through sustainable agriculture and rural development programs, there is an opportunity to deliver co-benefits. Eco-agriculture or SARD techniques help to sustain ecosystem services such as pollination and provision of soil fertility, as well as providing opportunities for carbon sequestration.

Meanwhile, in areas of intensive agriculture, 'precision' agricultural methods are increasingly used to target inputs directly (often to individual plants) at the appropriate times in the growing cycle. Using such technologies, inputs of fertilizer and of pesticides have been reduced, resulting in less run-off to watercourses and less damage to local ecology than in the past (Bongiovanni and Lowenberg-Deboer 2004).

Payments for ecosystem services

The value of ecosystem services has largely been overlooked by policy-makers and businesses. But, payments for ecosystem services (PES) such as carbon, water and some agri-environment benefits are becoming more common, particularly in developed countries (TEEB 2009). Such schemes are relatively uncommon in developing countries, although there are some examples such as China's 'Grain to Green' program which aims to take steep slopes out of cultivation for re-forestation (Feng 2005). Agri-environment schemes and PES could be further developed as a tool to contribute to both rural development and conservation of ecosystem services. Where food security is problematic, developing innovative payments for ecosystem services may help farmers through times of hardship and encourage more sustainable rural agriculture, providing a win-win for people and the environment.

Certification and standards

There is a wide variety of sustainable productions standards and certification schemes. Examples include: organic labeling (IFAOM); good agricultural practices (GLOBALGAP) and wildlife friendly produce (Rainforest Alliance). These schemes encourage soil management, water efficiency and wildlife friendly measures. In return, farmers get product differentiation, potentially premium prices and, in some cases, improved access to credit. Some large multinationals have also developed their own sustainability standards (see http://www.growingforthefuture.com/). Commodity "round-tables" are one attempt to improve the sustainability of commodity production. Major stakeholders who produce, buy and use a particular commodity such as oil palm agree criteria and guidelines for sustainable production. These may include adhering to local wildlife, pollution, and labour laws and adopting other specific criteria as appropriate. Commodity round-tables have now been established for cotton, palm oil, soya, sugar cane, biofuels, and aquaculture products, though their effectiveness has yet to be tested.

Despite guidance from FAO, certification has proved difficult for small-scale rural farmers who cannot afford the investments to meet enhanced standards and criteria. Consequently, one of the priorities under the New Partnership for African Development (NEPAD) was to develop an ecolabelling scheme appropriate for Africa. This presents a clear opportunity for engagement to ensure a fair deal for both smallholder farmers and the natural environment. It also offers a way of addressing the water, carbon and nutrient 'debts' that are effectively being exported by developed countries as they benefit from agricultural imports from developing countries (Hoekstra, 2003).

Removing perverse incentives for unsustainable production

Some unsustainable agricultural practices are supported through subsidies for overproduction, or subsidies for land clearance. These inappropriate policy measures present opportunities to improve investment, by targeting it at measures that can support the poor but do not harm the environment.

Protected areas and GIAHS

A traditional approach to biodiversity conservation is the establishment of protected areas. Use of protected areas to conserve biodiversity has been controversial because of their impacts on the rights of local people and their likely efficacy in times when climate envelopes are shifting and human population pressure is mounting (Izquierdo and Grau 2009). Fewer strict protected areas that preclude use are now being established and categories that recognise sustainable use are being used more frequently (Brockington and Igoe 2007). For example, Community Conserved Areas (CCAs) recently recognised as a new IUCN management category, represent a new and promising category of protected area. By 1997, nearly 60% of protected areas were classified as zones of agricultural or resource use (Zimmerer 2004) and the reality is that in many long inhabited and used landscapes, there is a gradient from 'wild' to 'cultivated' land.

Recognising this gradient, FAO have developed the Globally Important Agricultural Heritage Systems (GIAHS) approach that may present opportunities for synergy between the agricultural and conservation communities. The GIAHS concept was established to recognise the value of traditional farming systems and their associated agro-biodiversity and to ensure that traditional methods are not lost in the scramble to intensify and homogenise production (Harrop 2009). Recognition of these farming landscapes and of their biodiversity is the centre-piece of the Japanese Governments' Satoyama Initiative (http://satoyama-initiative.org/en/).

Protected areas alone cannot conserve biodiversity. They need to be considered as part of a whole landscape containing a matrix of different land-uses. It will be important to monitor land-use change within such a landscape and to identify agricultural encroachment into protected areas. New monitoring systems are urgently needed; this issue is addressed in the case study below.

Case study 2. Agriculture and web-based monitoring tools in Madagascar

Protected areas are still a mainstay of conservation. Some 30% of protected areas have agricultural land within their boundaries (McNeely and Scherr 2003, Molnar 2004); many small protected areas have become enclaves within a sea of agriculture. Despite this close association, there are few quantitative evaluations of agriculture's impacts on protected areas. Nevertheless, a qualitative evaluation of protected areas' effectiveness indicates that agriculture could be causing damage. The effects of development, such as arable agriculture, in areas surrounding protected areas as well as inside parks was reported as one of the five most frequent threats to protected areas (Leverington et al. 2008). Agriculture also affects a number of World Heritage sites in danger (http://whc.unesco.org/en/danger). The expansion of agriculture up to protected area boundaries is associated with increasing edge effects and there is concern that protected areas may be experiencing more subtle wildlife declines (Peres and Palacios, 2007).

This case study considers ways of monitoring deforestation and degradation associated with agricultural expansion by examining examples in Madagascar.

Why Madagascar?

Madagascar has a rich and unique fauna and flora, with some 19,000 endemic species and estimates of its diversity are still increasing (Dufils 2003; Mittermeir et al. 2008; Vences et al. 2009). But, this diversity is under threat. Madagascar has suffered 90% deforestation and extensive soil erosion (Harper et al. 2007). The central highlands have been cleared for croplands, pastures and agroforestry and both the eastern forests and the unique spiny forests of the south are fragmented and degraded (Figure 15).

Much of the deforestation has been blamed on colonial policies at the turn of the 19th century: 70% of the primary forest was lost between 1895 and 1930 (Jaroz 1993). More recently, the traditional tavy or slash-and-burn cycle has shortened from a 10-20 year rotation to just 3 years in some areas. This, in conjunction with an annual human population increase of 3%, and immigration from over-exploited areas, has been associated with reductions in soil fertility and abandonment of agricultural land (Ruthenberg 1980; Brooks et al. 2009). These losses are associated with an alarming level of national hunger (IFPRI 2009), and Madagascar is among the world's poorest countries.

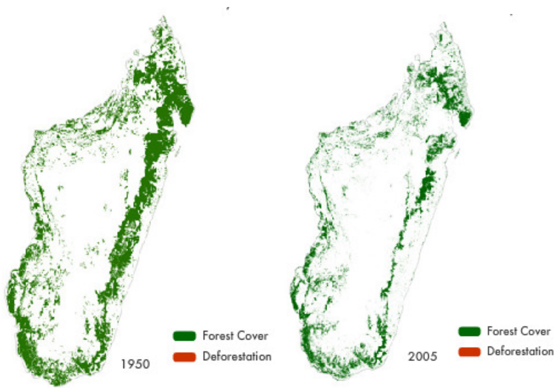


Figure 15 Comparison of forest cover in 1950 and 2005. Source Conservation International.

The establishment of protected areas here has often been controversial since local people, who do not have other livelihood options, are commonly disadvantaged (Keller 2008). One study indicated that restricting access to forest products in protected areas reduced household income by 18-19% of agricultural income (Shyamsundar and Kramer 1997). On the other hand, in times of political stability Madagascar's protected areas are important tourist attractions and local communities are becoming increasingly involved in park management and revenues sharing (http://e360.yale.edu/content/feature.msp?id=2217).

Supporting rural development to safeguard natural ecosystems

If the wildlife of Madagascar is to survive, conservation organizations need to recognize that rural development is essential. Agricultural extension work that supports better agricultural practices can help reduce pressure on forests. For example, intercropping with nitrogen-fixing legume species and retaining potassium-rich rice mulch both improve soil productivity (Styger et al. 2009). Conservation organizations could work with specialists in this field such as the Ecoagriculture partners, and the CGIAR partnership including CIFOR (Styger et al. 2009).

Carbon payments such as those through REDD mechanisms offer another way of increasing support to local communities. For example, Conservation International has been working with others to take advantage of the opportunities associated with certified and voluntary emissions reductions under the UNFCCC. The projects are able to sell carbon credits from reforestation and forest maintenance, bringing income for both local people and the government.

Monitoring with satellite imagery and the World-Wide Web

Such projects need to demonstrate their effectiveness at conserving forest as well as supporting livelihoods. New efficient monitoring methods are needed to do so (Sutherland et al. 2004). Several studies have shown that satellite imagery can be both inexpensive and a reliable way of monitoring vegetation change. For example, Whitehurst et al. (2009) used satellite photos to assess levels of deforestation and afforestation in Kirindy Mite NP in the west of Madagascar. Birdlife and its partners have tested the use of satellite imagery to monitor change in Important Bird Areas in Africa (Buchanan et al. 2009). While further ground-truthing is needed, the methodology has considerable potential as a tool for the future monitoring of conservation areas now that satellite images are widely and cheaply available (De Fries et al. 2010). Building on this Birdlife study and combining use of satellite imagery with web-based applications there is the potential to develop new tools to measure change very rapidly and accurately and to involve the wider community in assessments through the use of Citizen Science approaches (see http://citizensciencealliance.org/).

Such methods also have the advantage that that the maps and images they produce could also be used to engage the local and global communities through the internet and tools such as Google Earth.

Future work

The Macarthur foundation has already supported work to evaluate the effectiveness of conservation projects. By supporting the development of evaluation techniques that capitalize on remote sensing technologies and the World Wide Web, the foundation can help to monitor land use change in real time.

Case study 3. Conservation of grasslands and pastoral livelihoods. Development of integrated management strategies for landscape conservation in Kenya and Tanzania

Introduction

Grasslands have been a prime target for conversion to agricultural uses and many remaining grasslands are likely to be heavily affected by further conversion (Hoekstra et al. 2004, Alkemade et al. 2009). This impact is likely to be exacerbated if forests become increasingly valuable in economic terms because of payments for their stocks of carbon. This could prevent their conversion to other land uses and displace the threat to other ecosystems (Miles & Kapos 2008).

Grassland, savannahs and shrublands cover some 40% of the planet and support half of the world's endemic bird species and the greatest remaining concentrations of large-bodied mammals (Stattersfield 1998; White 2000). They also contain significant soil carbon stocks so further conversion of these ecosystems for agricultural use will result in greater carbon emissions (Trumper et al. 2009) (see Figure16a and b).

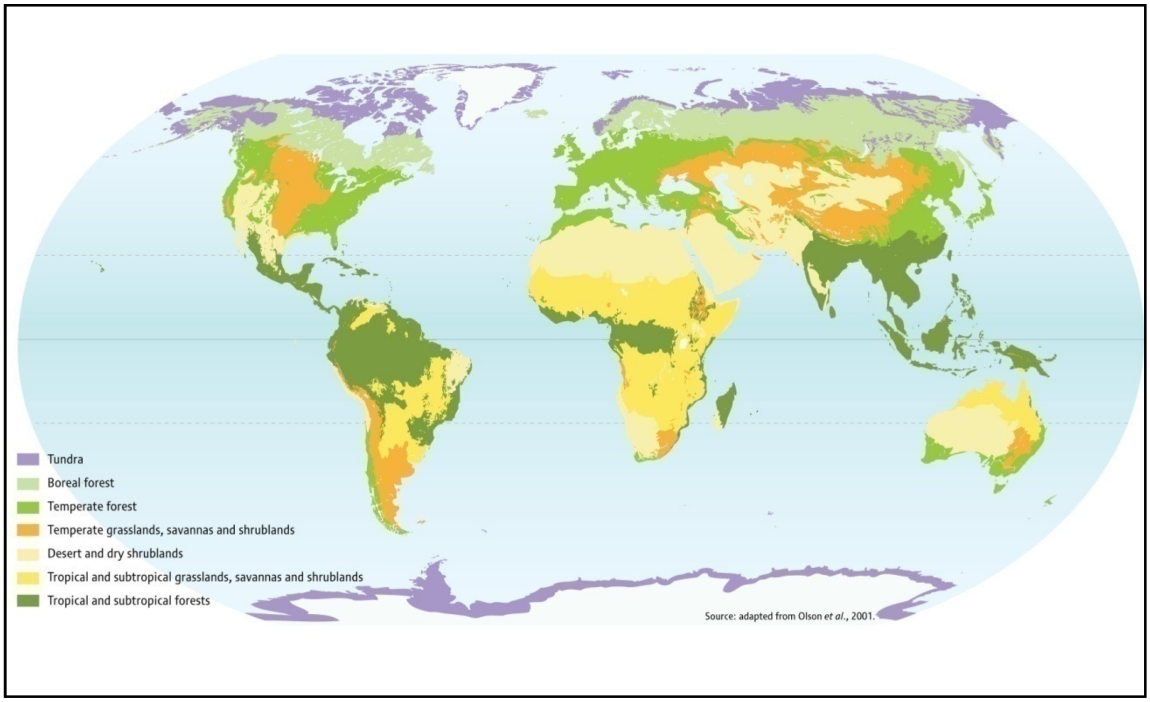


Figure 16a. The extent of grassland ecosystems. Source: Trumper et al. 2009.

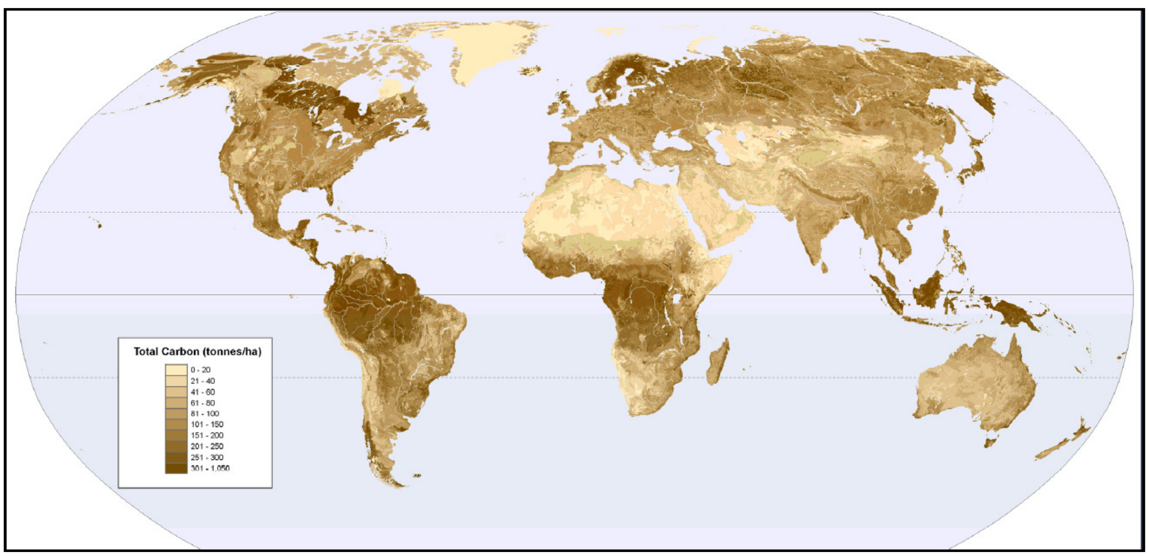


Figure 16b. Updated global soil carbon map. Source: Scharlemann et al. 2009.

Grasslands and savannah often have relatively low density human populations with pastoral lifestyles (Reid et al. 2004, Suttie, Reynolds and Batello 2005). This case study examines the value of pastoralism to ecosystem diversity, to highlight the importance of biodiversity outside protected areas. It also illustrates some of the integrated management tools discussed above.

The biodiversity values of pastoralism and threats to diversity

Ecological studies have demonstrated the importance of low density human populations in contributing to the ecological diversity of the savannah ecosystem in East Africa (Reid et al 2004). For example, Maasai settlements or bomas establish local nutrient hotspots because of higher levels of livestock dung there (Reid & Ellis 1995). Over the long term these nutrient hotspots are associated with a vegetation succession and higher levels of diversity. Old boma sites have the highest wildlife densities (Muchiru, Western & Reid 2009).

There synergies between pastoralists and wildlife populations are under threat. A growing human population and socio-economic pressures are inducing more of the Maasai to settle and develop agriculture (Homewood et al. 2009). For example, in one of the conservation areas, the area of agriculture increased by 76% between 1980 and 2000 with a 40% increase in livestock, resulting in overgrazing in the remaining pastoral areas (Okello 2009).

Many commentators think the move from pastoralism to settled agriculture will pose a growing threat to wildlife populations. In a comparison of two ecologically similar community ranches with different management strategies, Western et al. (2009), showed that sedentarisation of the human population, land privatisation and conversion to agriculture were associated with declining wildlife populations. Conversely, where communal land management was retained, wildlife populations increased. A 30 year examination of national wildlife populations throughout Kenya has shown that wildlife has declined both inside and outside protected areas due to ecological and management factors (Western et al. 2009a).

These declines have led to a call for quantitative assessments of the performance of conservation policies and for policies that promote integrated landscape practices that combine parks with private and community based measures (Western, et al. 2009b). It will also be necessary to find means of income generation other than farming. Examples include payments for ecosystem services, production of value added products from wildlife species or even compensation for foregone agriculture. In a recent example from Tanzania, tourist operators are paying a local community <u>not</u> to farm (Nelson 2010).

Future work

The MacArthur Foundation would be well placed to support work to examine the value of payments for ecosystem services in contributing to household income and reducing the need for agricultural expansion. To manage the biodiversity assets in this region, they will need to be measured and mapped and valued at both the local and global levels. Recognition of the importance of both a) connectivity between natural habitats at the landscape level, and b) the need for landholders to improve their livelihoods will be central to the maintenance of the landscape matrix.

Opportunities for policy integration

This report argues that agriculture and biodiversity policy need to be better integrated. There are immediate opportunities for doing so as some in the agricultural sector recognise the same need: the FAO Committee on Agriculture has noted that "the agriculture and environmental imperatives must be simultaneously tackled (FAO COAG 21). The World Bank is implementing *Agriculture for Development: an Action Plan 2010-2012*. The Global Forum on Agricultural Research (GFAR) which develops the research priorities for the CGIAR consortium held a Global Conference on Agricultural Research for Development (GCARD) in April 2010 to produce a research strategy for the next 10 years as a contribution to the re-organisation of the consortium. In the biodiversity arena, and associated with the Convention on Biological diversity, The Government of Japan and the United Nations Development Program (UNDP) on 10 May 2010, announced a commitment to collaborate on a financial program and knowledge mechanism as part of the Satoyama Initiative that aims to conserve biodiversity rich human-influenced natural environments, such as farmlands and production landscapes. This increased reference to the environment must now be turned into action, mechanisms are needed to ensure that land-use planning does integrate biodiversity considerations, At a regional scale, The New Partnership for Africa's Development (NEPAD's) Comprehensive Africa Agriculture Development Program (CAADP) provides an opportunity for biodiversity and agricultural policy integration in Africa. CAADP aims to revitalize development of agricultural policy in Africa. According to the African Environment Outlook 2 that profiles Africa's environmental resources as an asset for the region's development, different departments, often in different ministries, will need to co-operate to achieve this (AEO 2). Many donors are realigning their development programs at national levels to concentrate more on agriculture and climate change, which offers another opportunity.

Section summary

To facilitate negotiation of trade offs in land-use, biodiversity and agriculture professionals will need to understand one another better and develop ways of working together at policy, institutional and site-levels.

At the site level, sustainable intensification through precision agriculture, use of high yielding varieties and diversification in productive areas has an important role to play in feeding the world. Sustainable intensification is likely to be most appropriate in the developed and transition countries, initially. Restoration and re-use of degraded arable areas will also be important, taking account of the needs of local people and ensuring that land degradation is not used as an excuse to disenfranchise local pastoralists and others. In sub-Saharan Africa, techniques to increase soil fertility, reduce wastage from pest attack, store water and increase structural diversity through use of agro-forestry are urgently needed to increase productivity and lift landholders out of poverty. Investment in extension services is a major priority for development organizations and by linking agricultural and biodiversity curricula, the biodiversity community could generate increased understanding of the importance of biodiversity. To ensure the effectiveness of these site-based activities, further development of remote sensing and citizen science could provide a valuable tool for monitoring land cover change to ensure connectivity of wildlands is retained or enhanced as appropriate.

Conservation planning needs to move fully from its academic roots to a fully inclusive pragmatic activity that includes landowners, understands economic trade-offs and helps society to develop approaches to landscape management that value biodiversity whilst recognizing the need for livelihood generation. Eco-agriculture, with its mix of natural and productive lands has a role to play in this regard, but must also encompass sustainable intensification. Payments for ecosystem services could have an important role in providing incentives to maintain wildlands whilst appropriate eco-labeling schemes and examination of mechanisms for virtual trade in water etc may help to encourage more sustainable production and consumption.

4. Potential activities for MacArthur to address the impacts of agriculture

We have seen that the world's remaining biodiversity is gravely threatened by the future necessary expansion of agriculture for food and biofuel production. The MacArthur Foundation could make a unique and lasting contribution to managing this threat. This chapter outlines ways it could do so through supporting better integration of agriculture and biodiversity in sustainable landscapes. It identifies issues that are both of crucial global importance and that are amenable to implementation in local pilot studies. The case studies in previous chapters illustrate these approaches in sub-Saharan Africa, because the needs for agricultural development are greatest there. However, the proposed work would also be valuable in other hotspot countries of interest to the Foundation.

(i) Data synthesis, integration and mapping If concerns for ecosystems are to be better factored into decisions about agriculture, there needs to be more robust evidence of the relationships between the two and better projections of future changes. The Foundation could usefully support research in the following areas:

- **critical evaluation of the current models** that have produced very different projections of future land-use change. Sensitivity analyses and a review by modeling experts to examine the assumptions on which all the models are based would allow more confident predictions of change (see e.g. Solberg et al. 2007 who tested models used to predict trade in bioenergy commodities).
- **maps of potential land-use change and its impacts at national scales**. National maps could identify important biodiversity areas at risk, for example in the areas earmarked for agricultural expansion in Latin America and sub-Saharan Africa. Development of these maps will require compilation and integration of data on biodiversity, ecosystem services and socio-economic factors associated with the agricultural expansion. These maps would help to identify protected areas at risk and also areas of important biodiversity not protected under the PA system where alternative approaches would also be important.
- **case studies of the links between ecosystems and agriculture**. More robust evidence is needed of biodiversity's contribution to agricultural productivity; agriculture's impacts on biodiversity; and the identification of agricultural systems that deliver biodiversity, ecosystem services and productivity at the same time.

(ii) Integrating biodiversity and agriculture in policy and practice At present, biodiversity and agriculture professionals work in separate spheres, but the challenges facing each can best be met by working together. In this way, both could understand and manage differences in priorities. They could also better evaluate and distribute novel approaches to integrated land management, such as through payments for ecosystem services.

Softening the distinctions between land use for agriculture and for conservation might allow the movement of species through a matrix of agricultural and other land-uses. By examining where and how such connectivity has been achieved and assessing its impacts, lessons can be learned that inform future action in a world dealing with climate change. We also need to understand the links between patterns of consumption and landscape change. Priority work in these fields includes studies of the effectiveness of:

- **current connectivity and landscape approaches**;
- **agri-environment schemes for small-scale farmers in a variety of farming systems;**
- **payments for ecosystem services;**
- **mechanisms for securing strongholds of crop wild relatives, traditional crop varieties and races; and of**
- **mechanisms to spare land for biodiversity.**

Overarching this is the need for an **inter-disciplinary network of professionals** to test the science, make the case for biodiversity in trade-offs with agriculture, and to provide a forum to evaluate, test and distribute novel approaches to integrated land policy and management.

(iii) Developing assessment tools The effectiveness of new and existing approaches to managing land-use will need to be monitored and new techniques are needed. MacArthur could build on its previous investment in evaluating conservation outcomes by supporting work on:

- **web-based rapid assessment tools to measure changes in land-cover**. There is an opportunity to do this by combining advances in remote sensing with citizen science and the spatial mapping tools and databases available via the worldwide web.

(iv) Generating co-benefits between Foundations The MacArthur Foundation could influence major players in the development arena by working with foundations that support agricultural work. For example, the Gates Foundation supports agricultural research and data collection in sub-Saharan Africa. By supporting a complementary program to collect and map relevant data on biodiversity and ecosystem services, MacArthur could promote better data integration and planning for integrated landscape management and build a cadre of local professionals who can act to maintain biodiversity and deliver agricultural production. By partnering foundations interested in humanitarian work seeking to address issues of food security, the MacArthur Foundation will raise awareness of biodiversity issues and leverage added value. There are opportunities for working with partners to:

- **support collection of land-use and biodiversity data alongside agricultural data**;
- **build capacity of agricultural extension professionals** so that they understand biodiversity considerations and the value of ecosystem services;
- **build capacity of biodiversity professionals** to appreciate the role of food security and understand where agricultural practice can be improved.

Impacts

By developing such a program, the MacArthur Foundation will help to deliver an integrated approach to landscape management to assist policy makers to meet the triple challenge of delivering food security, addressing climate change and conserving biodiversity.

In addition to the ecosystem-based results that develop natural and physical capital, there will also be gains in social and economic capital, through education, development of stakeholder processes, support for equitable access to, and use of, resources, and sectoral integration. All these are key objectives to MacArthur's mission.

A future vision for agriculture would include sustainable management of agricultural ecosystems to meet global needs for food and livelihood security, whilst maintaining ecosystem services, as well as agricultural and wider biodiversity for future generations.

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Glossary

Agricultural biodiversity, according to the CBD, includes ecosystems, animals, plants and microorganisms related to food and agriculture.

Agroforestry – the growth of tree crops – often intercropped with other ground levels crops.

Ecoagriculture: is a fully integrated approach to agriculture, conservation and rural livelihoods, within a landscape or ecosystem context. It recognizes mutual interdependence among agriculture, biodiversity and ecosystem services. Ecoagriculture landscapes are mosaics of areas in natural/native habitat and areas under agricultural production. Effective ecoagriculture systems rely on maximizing the ecological, economic and social synergies among them, and minimizing the conflicts.

Ecosystem approach: a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.

Ecosystem services: the services and benefits to humanity provided by ecosystems include provisioning services such as food production; regulating services such as pest control, pollination etc; supporting services such as primary production and nutrient and water cycling and cultural services such as aesthetic values.

Ecosystem services important to agriculture: these include the following:
Regulation of pests and diseases;
Nutrient cycling, such as decomposition of organic matter;
Nutrient sequestration and conversion, as in Nitrogen-fixing bacteria;
Regulating soil organic matter and soil water retention;
Maintenance of soil fertility and biota; and
Pollination by bees and other wildlife.
At landscape scale, biodiversity-rich natural or managed areas (including forest, wetlands, hedgerows and woodland) adjoining or within agricultural landscapes also provide ecological services necessary for agricultural production.

Food Security: defined by FAO as "a situation in which all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1999). Others split food security into absolute availability; nutritional availability and distributional availability.

Intensification:
Agro-ecological intensification - Intensification of agricultural systems in an ecologically sound way based on local and traditional knowledge and scientific research, can blend improved knowledge about agricultural ecosystems and develop sustainable practices. Beneficial mixes of land use, including environmental corridors in landscapes that have been transformed by crop and livestock production, also raise the overall level of biodiversity in agricultural landscapes.

Intensive higher yield agriculture: High yields generated with high levels of inputs such as pesticides, herbicides and water.

Land-sparing agriculture: intensive agriculture that generates high yields to reduce the area of land required. Intensive agriculture could arguably become sustainable by adopting precision techniques to minimize waste and run-off.

Extensive lower yield agriculture/Wildlife-friendly farming: whereby on-farm practices are made as benign to wildlife as possible, at the potential cost of decreasing yields.

Precision agriculture: comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems. It adapts production inputs site-specifically within a field and individually for each animal and thus allows better use of resources to maintain the quality of the environment while improving the sustainability of the food supply.

Sustainable agriculture: comprises agricultural technologies and practices that maximize the productivity of the land whilst seeking to minimize damage both to valued natural assets (soils, water, air, and biodiversity) and to human health (farmers and other rural people, and consumers). It focuses upon regenerative and resource-conserving technologies,

and aims to minimize the use of harmful non-renewable and fossil fuel derived inputs.
Sustainable agriculture: methods include

- Mixed farming systems that incorporates crops, livestock and often trees to increase landscape and livelihood diversity and spread the risks.
- Organic agriculture makes no use of artificial chemicals.
- Integrated pest management makes use of crops/ plants that repel pests.
- Organic fertilizers such as legumes fix nitrogen in the soil naturally
- Crop rotation i.e. growing a different crop in a given field each year helps to reduce pest and pathogen build-up and restore soil fertility if the rotation includes nitrogen fixers.
- Recycling crop and animal wastes helps to restore nutrient balances and soil structure and water retention capacity.
- N o-till or minimum tillage agriculture avoids ploughing and disturbing soil structure and plant cover to reduce erosion.
- Inter or multi-cropping is used to produce different crops in a single field and generates field diversity and variety and thus reduces the danger to mono-cultures from challenges by novel pathogens and pests.
- C over crops help to protect against soil erosion and degradation.

Sustainable Agriculture and Rural Development (SARD) one of three issues related to agriculture and land management highlighted at UN Conference on Environment and Development in Rio in 1992 for which measures were adopted.

Zero tillage or no-tillage farming: Involves the planting of crop seeds amongst the crop residues without ploughing. May involve use of herbicide to reduce competitors.

Perennial vs annual agriculture. Perennial crops tend to be associated with less soil erosion, and contribute to the soil carbon reservoir and is generally recommended where possible..

Connectivity Conservation: aims to develop connections through the landscape, often associated with developing wildlife corridors.

Landscape planning, landscape design, and systematic conservation planning, are approaches that seek to develop coordinated approaches to land use. Systematic conservation planning, has biodiversity conservation at its core, and has tended to adopt academic approaches to identify the optimum areas in which to establish conservation areas.

Annex 1. Examples of other organizations working in the field of agricultural biodiversity

i) Agriculture Focus:

Satoyama Initiative of the UN University and Government of Japan linked with the CBD and UNDP. An initiative to promote societies in harmony with nature, in the words of the CBD Secretary General, the CBD is the Satoyama Initiative, the Satoyama Initiative is the CBD. It aims to conserve biodiversity through the inclusion of human communities – as opposed to preserving the environment by focusing exclusively on pristine environments where human activities almost do not exist. These landscapes, combining conservation with human-influenced areas, like farms or villages, are under threat from too much or too little intervention. The initiative seeks to raise their profile.

The Government of Japan together with the United Nations Development Program (UNDP) committed to collaborating on a financial program and knowledge mechanism during a side event to a meeting of the scientific body of the Convention on Biological Diversity (CBD) on 10 May 2010. Similar to the Land care approach of the World agro-forestry centre.
http://satoyama-initiative.org/en/

UN Food and Agriculture Organisation (FAO): undertakes mapping; data collection; capacity building; development of new techniques eg. agroforestry etc. FAO contributes to the CBD Program of Work on Agricultural Biodiversity, undertaking assessments of the status of agricultural biodiversity and working to develop conservation of wild relatives. FAO has developed Genetic and Indigenous Agricultural Heritage Systems (GIAHS) to conserve traditional crop systems. FAO has a number of relevant committees, namely the Committee on Agriculture (COAG); on Food Security (CFS) as well as the Commission On Genetic Resources For Food And Agriculture. FAO also has a department for Natural Resource Management. http://www.fao.org/

International Treaty on Plant Genetic Resources - the Secretariat of this treaty is housed with FAO and liaises closely.
http***://www.planttreaty.org/***

UN *International Fund for Agricultural Development* **(IFAD):** funds rural development projects specifically aimed at assisting the poorest of the poor; provides loans to developing country Member States on highly concessional, intermediate and ordinary terms for approved projects and programs, according to the borrower's per capita GNI; grants provided to institutions and organizations in support of activities to strengthen the technical and institutional capacities linked to agricultural and rural development.; grants are limited to 10% of the combined loan and grant program.
http://www.ifad.org

Consultative Group on International Agricultural Research (CGIAR): The CGIAR is a strategic alliance of members, partners and international agricultural centers that mobilizes science to benefit the poor. New strategy: Food for people, environment for people and policy for people. Mega Program (MP) 5: on Land water and ecosystems as well as MP 8 Mobilizing agricultural biodiversity for food security and resilience.
http://www.cgiar.org/
Africa Rice Center

- Bioversity International
- CIAT - Centro Internacional de Agricultura Tropical
- CIFOR - Center for International Forestry Research
- CIMMYT - Centro Internacional de Mejoramiento de Maiz y Trigo
- CIP - Centro Internacional de la Papa
- ICARDA - International Center for Agricultural Research in the Dry Areas
- ICRISAT - International Crops Research Institute for the Semi-Arid Tropics
- IFPRI - International Food Policy Research Institute
- IITA - International Institute of Tropical Agriculture
- ILRI - International Livestock Research Institute
- IRRI - International Rice Research Institute
- IWMI - International Water Management Institute
- World Agroforestry Centre (ICRAF)
- WorldFish Center

Development NGOs such as **CARE International, OXFAM** etc provide support to small rural farmers to assist them to develop sustainable livelihoods. http://www.careinternational.org.uk/; http://www.oxfam.org.uk/

Practical Action (the Intermediate Technology Development Group ITDG): working with poor people to develop the skills and technology that will enable them to build a better future. http://www.practicalaction.org.uk/

UNEP
Division of Early Warning and Assessment (DEWA); Division of Environmental Law and Conventions (DELC); Division of Environmental Policy Implementation (DEPI) is responsible for the implementation of environmental policy in order to foster sustainable development at global, regional and national levels; and is the focal Division for capacity building; **Division of Technology, Industry and Economics** DTIE- Paris Working with governments and the private sector to achieve responsible behaviour, positive investment and a cleaner environment; **DGEF:** land degradation, primarily desertification and deforestation a new focal area for UNCCD in October 2002 with a specific framework for intervention on Sustainable Land Management (SLM) in May 2003.In GEF 3 Land degradation fell under two Operational Programs (OP): Multifocal OP with a land degradation component, and the Sustainable Land Management .

Many **National Governments** also run global crop surveillance systems to provide early warning of shortages eg http://www.pecad.fas.usda.gov/cropexplorer/

ii) Conservation focus:

Global Harvest Initiative: members include John Deere, Monsanto, Dupont and ADM, WWF and Conservation International, TNC. **Mission:** By 2050, to eliminate the global productivity gap by sustainably doubling agricultural output to meet the needs of a growing world. Slogan: Farmer smarter and deliver better. http://www.globalharvestinitiative.org/harvest-2050/archives.php

The Keystone Alliance for Sustainable Agriculture: Field to Market - a steering committee of people representing interests from growers, conservation organizations, and companies throughout the agriculture and food supply chain to determine if a further dialogue would be helpful in 1) defining and motivating more sustainable production and 2) supporting and encouraging implementation of more sustainable measures. The premise of the effort is to encourage broad grower involvement while at the same time creating value to growers, consumers, and society in general. http://www.keystone.org/spp/environment/sustainability/field-to-market

Agriculture and Environment Coalition in the US: a coalition of environment and development organizations lobbying on food security and environment. The coalition includes Ecoagriculture Partners, World Wildlife Fund, Heifer International, Action Against Hunger USA, Save the Children, Bread for the World, Oxfam International, NASULGC, the Rodale Institute and World Vision International.

Flora and Fauna International (FFI): Runs the **Natural Value Initiative** – informing investors about environmental issues- includes agribusiness. Is currently working with the IFC Biodiversity and Agricultural Commodities Program to map High Conservation Value Forest at the landscape scale.

WWF: has helped create the following round tables: The Better Cotton Initiative; The Better Sugarcane Initiative; The Round Table on Responsible Soy; The Roundtable on Sustainable Palm Oil. It has worked with industry to develop the Forest and Marine Stewardship Councils, that address production of biomass and food from the wild and from plantations and aquaculture. Recently, WWF UK has launched a Food Policy unit that aims to tackle unsustainable production and consumption.

Wildlife Conservation Society (WCS): works to develop sustainable conservation friendly agriculture in the areas where it has projects, including organic farming, beekeeping, gardening, and carpentry enabling farmers to take advantage of international market demand for high-quality, organic products. It has developed the Conservation Cotton concept.

Conservation International (CI): works with businesses and at the landscape level to develop corridors and to support sustainable livelihoods in its project areas. It has recently developed a new Food Security Program to addresses the challenge of food security. We work at both the field and policy level to demonstrate that ecosystem health is essential to long-term food security and to promote sustainable livelihoods where agricultural production and resource conservation positively reinforce each other. http://www.conservation.org/learn/food_security/Pages/overview.aspx

The Nature Conservancy (TNC): works with farmers at the site and river level to encourage agri-environment uptake and is member of both the Keystone Alliance and Global Harvest Initiative. http://www.nature.org/pressroom/press/press4121.html

Birdlife International: Has a program of work related to reform of the EU Common agriculture Policy in 2013. Has worked with partners elsewhere on agriculture issues that impinge on IBAs, for example on a GEF supported project to mainstream the biodiversity of the Pantanal grasslands into agricultural considerations.

RSPB: undertakes research on its UK farmlands to examine means of biodiversity friendly agriculture. Has a Biofuels program and lobbies on UK and EU agriculture.

Agribiodiversity - a cross-cutting network of Diversitas: aims to inspire and facilitate interdisciplinary research for understanding the role of biological diversity in agricultural landscapes. Prioritizes science through 3 focii: **Focus 1 -** Assessing the drivers of biodiversity change in agricultural landscapes; **Focus 2 -** Understanding the role of biological diversity in agricultural landscapes for the provision of ecosystem goods and services**; Focus 3 -** Exploring integrated scenarios for the sustainable use of biodiversity in agricultural landscapes

THE AGRI-PROFOCUS PARTNERSHIP IN THE NETHERLANDS: BRINGS TOGETHER DONORS, BUSINESS AND OTHERS TO SUPPORT SMALL SCALE FARMERS.

Most of the major conservation undertake conservation planning at the site level, and are becoming more involved in developing forest carbon inventories, with remote sensing as part of REDD readiness projects. Conservation corridors are gaining favour, particularly in the more remote mountain areas. More wholistic approaches are needed that seek to incorporate the lowlands and plan for agricultural expansion linking up the different site-based approaches to provide a national overview.