The Debate on Biodiversity and Biotechnology

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ASK-FORCE contribution No. 11

Nearly 400 new references on biodiversity and Agriculture need to be screened and selected.

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1. Summary

The need for biodiversity on all levels is made clear (2): Biodiversity provides a source of significant economic, aesthetic, health and cultural benefits (3.). Relationships between biodiversity and ecosystems is given in a table (3.1.) and a new concept of sustainability with more emphasis on development and progress is given (3.2.)

Types of biodiversity are often used without clear definition: genetic biodiversity - species diversity and ecosystem diversity are all part of biodiversity (4.). A short chapter on unnecessary stigmatization of GMOs (5). Types of biodiversity, an overview (6) and distribution of biodiversity (7). The loss of biodiversity has many reasons (8): In chapter 9 crop biodiversity gets a closer look: the genome of transgenic crops is not basically different from non-transgenic crops (7.1.). Strikingly enough, the ancestral crop species chosen by the first farmers have lived in monodominant stands (7.2.). Agricultural biodiversity is characterized through high dynamics of all processes (7.3 and 7.4).

Chapter 8 deals with a series of proposals on how to enhance agricultural biodiversity through (landscape) management (8.1.), mixed cropping (8.2.), enhancing crop diversity through fostering orphan crops (8.3.) varietal mixture of genes and seeds of the same crop (8.4.), allow indirectly more diversity of non-target insects with the use of pest resistant transgenic crops and by reducing pesticide use and through no-tillage (8.5.), push-and-pull technologies (8.6.), better plant breeding (8.7), enhancing natural resistance with biotechnology (8.8.).

In an interlude chapter 9 on the activities of the protest industry and opponent scientists it is explained why the obvious success of GM crops is not really making progress in Europe.

In chapter 10, two case studies on GM crops are given with some detail on how those crops with widespread commercialization are helping efficiently to regain biodiversity in regions with intensive and industrial agriculture: Herbicide tolerant crops (10.1.) and pest tolerant Bt crops (10.2.)

In a final chapter 11, the health benefits of Bt maize are documented: transgenic Bt maize has much lower mycotoxin levels than non-transgenic maize.

2. The needs for biodiversity – the general case

Biological diversity (often contracted to biodiversity) has emerged in the past decade as a key area of concern for sustainable development (see 3.2), but crop biodiversity, the subject of this text, is rarely considered. The author’s contribution to the discussion of crop biodiversity in this chapter should be considered as part of the general case for biodiversity. Biodiversity provides a source of significant economic, aesthetic, health and cultural benefits. It is assumed that the well-being and prosperity of earth’s ecological balance as well as human society directly depend on the extent and status of biological diversity (Table 1). Biodiversity plays a crucial role in all the major biogeochemical cycles of the planet. Plant and animal diversity ensures a constant and varied source of food, medicine and raw material of all sorts for human populations. Biodiversity in agriculture represents a variety of food supply choice for balanced human nutrition and a critical source of genetic material allowing the development of new and improved crop varieties. In addition to these direct-use benefits, there are enormous other less tangible benefits to be derived from natural ecosystems and their
components. These include the values attached to the persistence, locally or globally, of natural landscapes and wildlife, values, which increase as such landscapes and wildlife become scarce.

Biological diversity may refer to diversity in a gene, species, community of species, or ecosystem, or even more broadly to encompass the earth as a whole. Biodiversity comprises all living beings, from the most primitive forms of viruses to the most sophisticated and highly evolved animals and plants. According to the 1992 International Convention on Biological Diversity, biodiversity means “the variability among living organisms from all sources including, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part” CBD (1992). It is important not to overlook the various scale-dependent perspectives of biodiversity, as this can lead to many misunderstandings in the debate about biosafety. It is not a simple task to evaluate the needs for biodiversity, especially to quantify the agro ecosystem biodiversity vs. total biodiversity Purvis and Hector (2000, Tilman (2000).

One example may be sufficient to illustrate the difficulties: Biodiversity is indispensable to sustainable structures of ecosystems. But sustainability has many facet’s, among others also the need to feed and to organize proper health care for the poor. This last task is of utmost importance and has to be balanced against biodiversity per se, such as in the now classic case of the misled total ban on DDT, which caused hundreds of thousands of malaria deaths in Africa in recent years, the case is summarized in many publications, here a small selection: Attaran and Maharaj (2000, Attaran, Roberts, et al. (2000, Curtis (2002, Curtis and Lines (2000, Horton (2000, Roberts, Manguin, et al. (2000, Smith (2000, Taverne (1999, Tren and Bate (2001, WHO (2005)

The theory of biodiversity, not the central topic here, needs renewed attention, and the old dilemma of species limits and definitions is not really solved, it needs, besides the indispensable field experience of biodiversity experts, which is often seriously underestimated, also new attention in molecular insight, here just one paper which underpins this statement: (Neto C. 2016)


"According to the ‘species-as-individuals’ thesis (hereafter S-A-I), species are cohesive entities. Barker and Wilson recently pointed out that the type of cohesion exhibited by species is fundamentally different from that of organisms (paradigmatic individuals), suggesting that species are homeostatic property cluster kinds. In this article, I propose a shift in how to approach cohesion in the context of S-A-I: instead of analyzing the different types of cohesion and questioning whether species have them, I focus on the role played by cohesion in the identity of individuals. This shift allows us to recognize why cohesion matters to S-A-I, as well as to reconceive the analogy between species and organisms (paradigmatic individuals), and also allows us to highlight the context sensitivity of both “cohesion” and “individuals.” From this perspective, I identify two problems in Barker and Wilson’s argumentation. Firstly, the authors fail to recognize that species are individuals even if they do not have the same type of cohesion that organisms have. Secondly, their argument relies on a misinterpretation of S-A-I. I conclude that species cohesion is still best framed as a feature of species individuality rather than a feature of species as homeostatic property cluster kinds. The arguments presented here contribute to the re-articulation and re-evaluation of S-A-I in the face of contemporary discussions." From (Neto C. 2016)

Neto is contradicting Barker and Wilson 2010 about their species cohesion theory:


Since the Modern Synthesis, the view that species are cohesive entities held together by gene flow has moved from being a theoretical insight amongst systematists to common knowledge amongst biologists. The plant biologist Vern Grant provides a classic and succinct expression of this view, hereafter simply The View, in saying that "species populations are homogenized and integrated by gene flow."1 As one of us has recently detailed, several biologists have challenged the empirical
adequacy of The View over the past forty-odd years. Nevertheless, most biologists, including many phylogenetists, have thought that species are cohesive entities, and the idea that gene flow is the primary cause of this cohesion continues to hold sway.

The classic paper of Ehrlich and Raven doubts that gene flow is given such importance: (Ehrlich & Raven 1969)


"Most contemporary biologists think of species as evolutionary units held together by gene flow. For instance Mayr (1) writes “The non-arbitrariness of the biological species is the result of internal cohesion of the gene pool.” Merrell (2) states “The species is a natural biological unit tied together by bonds of mating and sharing a common gene pool.”

This idea is founded in the pioneering work of Dobzansky, Mayr, Stebbins, and others integrating the theory of population genetics with laboratory and field experiments and observations to produce the neo-Darwinian or synthetic theory of evolution. These workers quite logically concluded that differentiation of populations would be prevented by gene flow, and they focused their discussions of speciation on various means of interrupting that flow. In other words, they emphasized the role of mechanisms isolating populations from one another. Until quite recently there has been little reason to question this view. In the past few years, however, growing evidence from field experiments has led us to re-evaluate the processes leading to organic diversity, and to conclude that a revision of this section of evolutionary theory is in order.

In this paper we suggest That many, if not most, species are not evolutionary units, except in the sense that they (like genera, families, and so forth) are products of evolution. We will argue that selection is both the primary cohesive and disruptive force in evolution, and that the selective regime itself determines what influence gene flow (or isolation) will have. Threefold evidence is presented for this. We will show that (i) gene flow in nature is much more restricted than commonly thought; (ii) populations that have been completely isolated for long periods often show little differentiation; and (iii) populations freely exchanging genes but under different selective regimes may show marked differentiation.

We finally reiterate the point (3) that a vast diversity of evolutionary situations is subsumed under the rubric “speciation,” and that this diversity tends to be concealed by an extension of a taxonomic approach from the products of evolution to the processes leading to the differentiation of populations. Euphydryas editha and Festuca rubra are both species to the taxonomist, but knowing this does not tell us if they are evolutionary units or how they evolved. Nor does it permit us to guess how similar are their evolutionary pasts, in what way they are similar today, or to predict anything about their evolutionary futures.” From (Ehrlich & Raven 1969)

More citations here from Barker

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### Table 1 Primary goods and services provided by ecosystems

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Goods</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agro ecosystems</td>
<td>Food crops</td>
<td>Maintain limited watershed functions (infiltration, flow control, partial soil protection)</td>
</tr>
<tr>
<td></td>
<td>Fiber crops</td>
<td></td>
</tr>
</tbody>
</table>

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### 3. Relationship between biodiversity and ecological parameters

The relationships between biodiversity and ecological parameters, linking the value of biodiversity to human activities are partially summarized in Table 1 (co-authored with Jonny Gressel Gressel [2007]).
<table>
<thead>
<tr>
<th>Ecosystem Type</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop genetic resources</td>
<td>Provide habitat for birds, pollinators, soil organisms important to agriculture</td>
</tr>
<tr>
<td></td>
<td>Build soil organic matter</td>
</tr>
<tr>
<td></td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td></td>
<td>Provide employment</td>
</tr>
<tr>
<td>Forest ecosystems</td>
<td></td>
</tr>
<tr>
<td>Timber</td>
<td>Reduce air-pollutants, emit oxygen</td>
</tr>
<tr>
<td>Fuel wood</td>
<td>Cycle nutrients</td>
</tr>
<tr>
<td>Drinking and irrigation water</td>
<td>Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization)</td>
</tr>
<tr>
<td>Fodder</td>
<td></td>
</tr>
<tr>
<td>Non-timber products (vines, bamboos, leaves, etc.)</td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td>Food (honey, mushrooms, fruit, and other edible plants; game)</td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Generate soil</td>
</tr>
<tr>
<td></td>
<td>Provide employment</td>
</tr>
<tr>
<td></td>
<td>Provide human and wildlife habitat</td>
</tr>
<tr>
<td>Freshwater ecosystems</td>
<td></td>
</tr>
<tr>
<td>Drinking and irrigation water</td>
<td>Buffer water flow (control timing and volume)</td>
</tr>
<tr>
<td>Fish</td>
<td>Dilute and carry away wastes</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>Cycle nutrients</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td></td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td></td>
<td>Provide aquatic habitat</td>
</tr>
<tr>
<td></td>
<td>Provide transportation corridor</td>
</tr>
<tr>
<td></td>
<td>Provide employment</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
<tr>
<td>Grassland ecosystems</td>
<td></td>
</tr>
<tr>
<td>Livestock (food, game, hides, fiber)</td>
<td>Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization)</td>
</tr>
<tr>
<td>Drinking and irrigation water</td>
<td>Cycle nutrients</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Reduce air-pollutants, emit oxygen</td>
</tr>
<tr>
<td></td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td></td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td></td>
<td>Generate soil</td>
</tr>
<tr>
<td></td>
<td>Provide human and wildlife habitat</td>
</tr>
<tr>
<td></td>
<td>Provide employment</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
<tr>
<td>Coastal and marine ecosystems</td>
<td></td>
</tr>
<tr>
<td>Fish and shellfish</td>
<td>Moderate storm impacts (mangroves; barrier islands)</td>
</tr>
<tr>
<td>Fishmeal (animal feed)</td>
<td>Provide wildlife (marine and terrestrial) habitat</td>
</tr>
<tr>
<td>Seaweeds (for food and industrial use)</td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td>Salt</td>
<td>Dilute and treat wastes</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td>Petroleum, minerals</td>
<td>Provide harbors and transportation routes</td>
</tr>
<tr>
<td></td>
<td>Provide human and wildlife habitat</td>
</tr>
<tr>
<td></td>
<td>Provide employment</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
<tr>
<td>Desert ecosystems</td>
<td></td>
</tr>
<tr>
<td>Limited grazing, hunting</td>
<td>Sequester atmospheric carbon</td>
</tr>
<tr>
<td>Limited fuelwood</td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Provide human and wildlife habitat</td>
</tr>
<tr>
<td>Petroleum, minerals</td>
<td>Provide employment</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
<tr>
<td>Urban ecosystems</td>
<td></td>
</tr>
<tr>
<td>Space</td>
<td>Provide housing and employment</td>
</tr>
<tr>
<td></td>
<td>Provide transportation routes</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
<tr>
<td></td>
<td>Maintain biodiversity</td>
</tr>
<tr>
<td></td>
<td>Contribute aesthetic beauty and provide recreation</td>
</tr>
</tbody>
</table>
4. A new concept of sustainability

With this introduction, the following sustainability scheme can easily be understood: The left column is really the most important one when it comes to necessities of mankind: But in order to reach sustainability in agriculture, we must adopt progressive and innovative management strategies, it will be necessary to combine the most efficient and sustainable agriculture production systems. Details can be seen in the fig. 1. It should be made clear that agriculture needs to become highly competitive, innovative and there is an urgent need to produce more food on a smaller surface. But all efforts will be in vain, if we do not succeed to make substantial progress in the fields of socio-economics and technology.

Unfortunately, the concept of sustainability is often seen in combination with an extremely defensive concept of the precautionary “principle” – which actually has to be called correctly the precautionary approach Böschen (2009), it is often abused as a defence against the introduction of GM crops.

If we want to aim at a more sustainable world, it needs more than the usual defensive means advocated.

Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report UN-Report-Common-Future (1987):

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

The concept of needs, in particular the essential needs of the world’s poor, to which overriding priority should be given; and

The idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs”

Sustainability is usually understood (and clearly abused) as a definition with a rather defensive spirit, but if one reads it in its original content, then the words envision uncompromisingly the way forward – asking not only for conservation, but also for development and management of patterns of production and consumption.

The declaration of the OECD, authored by Yokoi Yokoi (2000) catalogues a range of concrete measures and rules in order to achieve a more sustainable agriculture. It is remarkable, that the proposed indicators do not distinguish between farming with or without transgenic crops.

The scheme in Figure 1 meets those needs and asks for an intransigent view into the future. The three column model has been chosen with care, and as one can see:

4.1. Revisiting the original Brundtland definition of sustainable development

Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report UN-Report-Common-Future (1987)

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world’s poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs” UN-Report-Common-Future (1987)

Sustainability in the sense of Brundtland is usually mis-understood as a definition with a rather defensive spirit, but if one really reads it in its original content, then the words envision uncompromisingly the way forward – asking not only for conservation, but also for the development and management of sustainable patterns of production and consumption. One should be aware of an extensive theoretical discussion on a “principle based approach for the evaluation of sustainability” as elaborated by Hermans and Knippenberg (2006). They present an intricate and purely theoretical
philosophical map of inter-twined factors of sustainability, where the main elements are justice (in our model equity) and resilience. In our model resilience is included in a pragmatic way, where good fields of activity and research meet the demands of resilience (e.g. This is done in a mixture of the two basic views about the role of science: The deterministic view where science tells us something about the true nature of the real world and a more constructivist view where scientific understanding is to a large degree socially constructed, in order to avoid the polarizing view of Hermans et al. 2006.

A move forward to a more pragmatic, more concrete concept of sustainability is offered by the OECD with a focus on agriculture: The declaration of the OECD, authored by Yokoi (2000) catalogues a range of concrete measures and rules in order to achieve a more sustainable agriculture. It is remarkable, that the proposed indicators do not distinguish between farming with or without transgenic crops. See in particular the Table 11.1 in the link given in the reference: it contains a comprehensive list of agricultural sustainability factors.

4.2. Redefining Sustainability for Agriculture and Technology, see fig. 1

![Sustainable World Diagram](image-url)

Fig. 1 A new concept of a sustainable world, in AGRICULTURE based on renewable natural resources, knowledge based agriculture: Organic Precision Biotech Ag, Balance local production with global trade. In SOCIO-ECONOMICS Equity: reconcile traditional knowledge with science, foster biomimetics, reduce agricultural subsidies, global dialogue including new creative capitalism. In TECHNOLOGIES Innovation supported by artificial intelligence, influence evolution, new technologies to process and use of housing, food, energy.

1. Agriculture, (left column fig.1)
Agriculture is the source of renewable natural resources, including energy. Its worldwide potential remains largely underexploited. Industrial agriculture is still largely stuck in the petrochemical age, and organic agriculture panders too much to urban nostalgia and thus wastes its potential to contribute to the solution of the real problems on this planet. The main goals of sustainable agriculture are instead "to foster renewable resources, knowledge based agriculture Trewavas (2008)

The mistakes on the side of industrial agriculture have been already anticipated by one of the creators of the green revolution: Swaminathan Swaminathan (1968) published early warnings on unwelcome developments related to the Green Revolution: "The initiation of exploitive agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity."

Organic agriculture may be part of the solution but it is currently also part of the problem. For a more extensive discussion of those "organo-transgenic" strategies see chapter 6.

Another possible technology driven progress may come from precision farming, which has developed from a high tech domain in developed countries like the USA, where considerable energy savings have been realized and remote control is used for field experimental design Gerhards, Gutjahr, et al. (2012). This emerging variant of industrial farming is developing rapidly in the United States, and it’s a management system is based mainly on satellite monitoring, it helps saving energy and time and can lead to a more ecological farming with higher yield Godwin, Richards, et al. (2003, Godwin, Wood, et al. (2003, Kitchen (2008, Kitchen, Sadduth, et al. (2005, Leithold and Traphan (2006, Shanahan, Doerge, et al. (2004, Shanahan, Kitchen, et al. (2008, Slaughter, Giles, et al. (2008a, Slaughter, Giles, et al. (2008b, Thenkabail (2003). Methods of precision farming, applied in an acceptable manner, do not directly contradict the main rules in organic and integrated farming and should seriously be considered as helpful auxiliary methods.

Another highly promising technology development field can be summarized under Fertigation Gosenpud, Srinivasan, et al. (2011) a technology dramatically saving water with subterranean irrigation. It offers as a minimal technology in rural settings new elements of social entrepreneurship, especially also in developing countries.

In addition, we need to give more attention to underutilized crops Gressel (2007a) and new realms of research are opening with a more systematic approach by learning from nature for the development of new technologies with biomimetics Paris, Burgert, et al. (2010). This leads to the last, the more general view of technologies:

Balancing local food production against global agricultural trade will be a challenge, since there will be increasing divergence of global demand (that is constantly increasing due to income growth in poor countries) and supply (which is stagnating in view of lack of investment in agricultural productivity). As a consequence, there will be pressure to not just enhance local food production but also increase the share of food that is globally traded. After all, the food importing countries will be the ones that are most vulnerable to price shocks. The economic basis should be important, but local social networking and life need to be taken into account as well and protected from protectionism, also under the false premise of import bans for GM crops.


Even though the Green Revolution was a great success, there were also detrimental effects such as the upsurge of new mass pest insects, growing insect resistance against widely used pesticides and negative effects on the soil fertility and a rising number of herbicide resistant weeds. Swaminathan was one of the fathers of the Green Revolution who recognized its shortcomings. In his call for an Evergreen Revolution in 2006 Kesavan and Swaminathan (2008, Swaminathan (2006) he argues, that ensuring continuous productivity increases requires a re-thing of sustainable agriculture: a new emphasis on better infrastructure, crop rotation, sustainable management of natural resources as well as progressive enhancement of soil fertility and overall biodiversity. These goals can only be achieved by combining traditional and high technology knowledge. Logically, detrimental effects like upcoming weed and pest resistance (new resistant species moving into a huge ecological niche) are also likely to become serious problems for large-scale farmers that adopt new high tech (GM)-crops. But these are well-known problems from experience with conventional and traditional agriculture as well, the only difference is that these problems can be addressed more quickly and more effectively with new technological means available (modern breeding, conservation tillage, mixed cropping etc.).

2. Socio-Economics (middle column fig. 1)

The foundation of the pillar ‘Socio-Economics’ is based on the fact that all economic and technological change relies directly or indirectly on societal approval. Its outcomes must be considered socially acceptable Osseweijer, Ammann, et al. (2010). Modern biotechnology faces an
acceptance problem and its outcomes are perceived as socially unsustainable. But if one follows the public debate on genetic engineering in agriculture in Europe, it becomes increasingly obvious that the critical arguments actually never refer to genetic engineering as such but they refer to problems related to industrial (petrochemical) agriculture with its often exaggerated monocultures without sufficient crop rotation Broer, Busch, et al. (2009), Broer, Jung, et al. (2011), Taube, Krawinkel, et al. (2011). Interestingly, the fact that over 80% of those farmers having adopted GM crops in developing countries are small-scale farmers is rarely mentioned in these public debates because they are inconsistent with the conviction that this technology only benefits the big and wealthy and should be basically unsustainable. No one should underestimate the risk of increasing concentration in industry, but opponents are actually encouraging this trend by pushing for ever more expensive regulation on GM crops, ensuring that the small players either go out of business or become part of the big players (Miller 1996). The socio-economic dimension should therefore be addressed by increasing the quality of the public debate, support public understanding of science especially in the education system, fostering global dialogue and working towards reconciliation between the polarized debates by finding a common denominator among the opposing parties in the spirit of an open end discourse Ammann and Papazova Ammann (2004). Terms like ‘Natural Capitalism’ Schweikart (2010) or ‘Sustainable Development in Business’ Sneddon, Howarth, et al. (2006) should have this integrative power to facilitate joint action. New visions can only stem from a new culture of looking at innovation, what we really need is a new question culture, Papazov Ammann (2010).

Another crucial component of socio-economics is the need for more social equity. The financial crisis combined with the global food crisis started to escalate for in 2008 and policy makers have still not found proper means to stop these crises. As a result social inequality as well as hunger and starvation continue to increase. In order to stop this trend, it will be imperative to reduce the huge agricultural subsidies paid to the farmers in the developed world. Even if some of these subsidies continue to be legal under the WTO Agreement on Agriculture they are still distorting trade and thus harming farmers in developing countries. They should therefore wear a warning tag called ‘protectionism’. Codron, Siriex, et al. (2006), Devos, Maeselee, et al. (2008). In this context, the case of New Zealand proves that export- oriented agriculture does not necessarily undermine efforts to protect the environment, maintain local traditions and reduce rural poverty Aerni (2009), Aerni, Rae, et al. (2009). Here again, solutions may be found in new technologies and strategies Clarke and Ayegman (2011).

Lots of empirical research revealed that the popular argument that developing countries are in the grip of multinationals is a myth Atkinson, Beachy, et al. (2003), Beachy (2003), Chrispeels (2000), Cohen (2005), Cohen and Galinat (1984, Cohen and Paarlberg (2004), Dhlamini, Spillane, et al. (2005). Instead of keeping ourselves busy with finger pointing to possible scapegoats that the global sustainability debate should focus on the creation of new form of capitalism that would help mankind to overcome the global economic crisis that persists now for over 3 years and facilitate sustainable global change through combination of traditional knowledge with modern science. For that purpose, we need to mobilize science and technology for development. It will however have to be based on a bottom-up approach that encourages local entrepreneurs to make effective use of the new knowledge and opportunities. They will be the ones that most likely to come up with locally sustainable products and services because they know how to successfully tailor new technologies to particular needs in their respective region. But in addition, there is also a need for science to reform itself. In the new age of biology it is necessary to abandon the inherited mechanistic and reductionist views of science. Besides new breeding technologies such as Zink finger transgenesis Shukla, Doyon, et al. (2009) allow a targeted insertion of transgenes in higher plants by creating double stranded breaks in DNA, also the de-novo engineering of a Transcription Activator-Like Effectors (TALE) will allow for a more efficient and targeted gene transfer Mahfouz, Li, et al. (2011).

3. Technology Evolution (right column fig.1)

It represents a holistic view of technological evolution. The general problem of technology is that it means different things to different people. It can be linked to invention, profits, problem-solving, or causing problems etc. Public disagreement about the role of technology is mainly the result of an imprecise understanding of its nature. In fact technology neither represents something good or bad but is rather based on a system that exploits certain effects in nature and puts them to use with purpose of addressing specific human needs Arthur (2011). It evolves through a process of trial and error. In other words, it constantly improves through learning from mistakes. At the very outset, a new technology is perceived and debated as either something useful or something risky but with its ubiquitous use it eventually fades into the background and is taken for granted unless there is a sudden loss of confidence due to a serious accident. Modern biotechnology faces the odd situation that it continues to be debated in Europe as a new and potentially risk technology that needs further risk research; while in many other parts of the world, modern biotechnology in general and genetically modified crops in particular have become a reality in the production and consumption of food in many other parts of the world for the past fifteen years. Growing evidence from these adopting countries shows that green biotechnology has indeed the potential to contribute to sustainable and equitable agricultural production can preserve biological diversity through sustainable intensification of agriculture on land already under cultivation, is safe to eat for animals and human beings and helps reduce greenhouse gas emissions. Here we present a few examples of conservation tillage effects, which are largely made possible in combination with herbicide tolerant GM crops and the use of glyphosate herbicide: Cerdeira, Gazziero, et al. (2007), Christoffoleti, Galli, et al. (2008). No one should argue that no mistakes happened in the course of its widespread adoption with agricultural management, but it is the great strength of technological evolution that it actually learns from mistakes. A recent correction of all the false accusations against the use of glyphosate has been published by Williams Amy Lavin, Watson Rebecca E., et al. (2012), heavily criticizing all the incredibly wrong lab procedures to construct “alarming” toxicological results LeVaux Ari (2012) and e.g. Mesnage, Clair, et al. (2012), pointing at the notoriously sloppy or outright wrong laboratory practices of a small group of “independent” scientists of the research group of CRiGEN from France, see the previous remarks about Séralini above. There is lots of
evidence, that this scaremonger attitude of the protest industry is also influencing science and worldwide regulation: Giddings, Potrykus, et al. (2012, Miller, Morandini, et al. (2008a), there is urgent need for correction. We should not follow certain stakeholders like Greenpeace and Friends of the Earth in Europe that seek popularity with consumers and taxpayers by proposing populist decision making in the name of the precautionary principle – unfortunately the news press happily follows those scaremonger schemes Miller (2009a). Merely postponing decisions is indeed not conducive to sustainable change. Technological evolution seems to suffer sometimes also from wrong understanding of evolution. The term deplorably still contains – often not consciously – some elements of creationism Weber, Rao, et al. (2009) – and this not only with opponents of gene splicing. It will be important to move beyond such a dualist mindset and make clear, that for many years we have taken human evolution into our own hands through modern medicine, and we need to deal with the problems and prospects by following along new evolutionary views. Modern breeding has the potential to enlighten the population, if done in an ethically acceptable way and if communicated properly. The tasks will grow over the next decades, and in many fields of science we are already now heavily dependent on calculation power; therefore, let’s make sure that mathematical algorithms can be translated into useful artificial intelligence in the service of mankind. All new and emerging technologies must be considered (and of course regulated in a reasonable way) in order to enhance food production and the livelihood of mankind. The slogan “we have only one planet” reflects a healthy attitude of precaution because it appeals also to our responsibility to take evolution as a whole into our own hands. After all we live in the period of the ‘Anthropocene’ where most problems caused by mankind and affecting mankind can only be addressed by mankind itself. This requires a close and conscious look at the cultural side of human evolution as a whole with all its consequences for us. It will need historical and philosophical scrutiny, going far beyond the usual disputes on technologies Azzone (2008, Mesoudi and Danielson (2008). Finally, it should be stated, that monothetic religions do not have basic evolutionary or theological objections against bioengineered crops. For example, two publications from the Pontifical Academy of Science are proof of this view: Potrykus and Ammann Klaus (2010, Potrykus, Arber, et al. (2010). Also in the Islamic world there is no basic resistance against modern biotechnology, as the Halal statements show: Recent international conferences on the highest Islamic level have questioned the validity of arguments against genetic engineering in agriculture Sharia Compliance (2010, World Halal Forum (2010).

The most recent report on sustainability coming from the United Nations confirms the Brundtland report again:

United Nations. (20150812):


"27. We will seek to build strong economic foundations for all our countries. Sustained, inclusive and sustainable economic growth is essential for prosperity.

This will only be possible if wealth is shared and income inequality is addressed. We will work to build dynamic, sustainable, innovative and people-centred economies, promoting youth employment and women’s economic empowerment, in particular, and decent work for all. We will eradicate forced labour and human trafficking and end child labour in all its forms. All countries stand to benefit from having a healthy and well-educated workforce with the knowledge and skills needed for productive and fulfilling work and full participation in society. We will strengthen the productive capacities of least developed countries in all sectors, including through structural transformation. We will adopt policies which increase productive capacities, productivity and productive employment; financial inclusion; sustainable agriculture, pastoralist and fisheries development; sustainable industrial development; universal access to affordable, reliable, sustainable and modern energy services; sustainable transport systems; and quality and resilient infrastructure.” From United Nations (20150812)

A comprehensive overview on how sustainability could be organized in an ‘adaptive learning process’ is offered by Reed, Fraser, et al. (2006): The good thing about this scheme is that it is open ended and conceived as a learning process, thus having the near automatic capability of adaptation to local needs.
On a more theoretical level, but in a comparable process spirit Phillis and Andriantiatsaholiniaina (2001) have chosen the approach over fuzzy logic, followed by a recent publication within the same framework: Phillis, Kouikoglou, et al. (2010), giving a truly holistic picture including corporate structures.

"Many people believe that our society is at the crossroads today because of societal and environmental problems of scales ranging from the local to the global. Such problems as global warming, species extinction, overpopulation, poverty, drought, to name but a few, raise questions about the degree of sustainability of our society. To answer sustainability questions, one has to know the meaning of the concept and possess mechanisms to measure it. In this paper, we examine a number of approaches in the literature that do just that. Our focus is on analytical quantitative approaches. Since no universally accepted definition and measuring techniques exist, different approaches lead to different assessments. Despite such shortcomings, rough ideas and estimates about the sustainability of countries or regions can be obtained. One common characteristic of the models herein is their hierarchical nature that provides sustainability assessments for countries in a holistic way. Such models fall in the category of system of systems. Some of these models can be used to assess corporate sustainability." From Phillis, Kouikoglou, et al. (2010)

5. The Issue: unnecessary stigmatization of GMOs
Genetically engineered crops are often taken automatically for the main reason of biodiversity loss. In a special treatment on the background of the Golden Rice debate the author is describing in detail the unfortunate cultural, social and psychological situation in the western world, simply summarized the ardent, ever-lasting toxic debate is the result of a lack of real fear topics in our ultra-safe society with blatant energy and food waste. So many people are “happy” to get afraid of anything presented with a “convincing” rhetoric.

The scientific basis of the biosafety assessment in Europe and the Cartagena-Protocol is designed on the erroneous principle of focusing on the processes called “Genomic Misconception”.

As Nobel Prize

Fig. 2  Adaptive learning process for sustainability indicator development and application, from Reed, Fraser, et al. (2006).
winner Werner Arber has stated in many publications, the molecular processes which promote gene transfer from one organism to the other are based on the same mechanisms as natural mutation, so the resulting stigmatization of GMOs is scientifically not justified. Arber (2010). All details can be studied in another publication of the author, including the unfortunate history of the EU and the Cartagena Protocol regulation: Ammann Klaus (2014). Actually, the Genomic Misconception is the basic mistake of molecular views on modern breeding, since it fixed very early the concept of process-oriented regulation. Canada and partially also the USA (with some other countries like Argentina and Australia) adhered right from the beginning to the product-oriented view, which also is the basis for a completely different approach to risk assessment.

Stigmatization is made easy and normal with the concept of process–oriented regulation. And there are many other reasons for such stigmatization.

There are numerous other false stigmatization claims of this kind, such as Vandana Shiva gives in her frequent world tours on preaching for the poor (with a confirmed honorary fee of 40’000 US$ and a first class air ticket of 10’000 US$ guaranteed!) lots of frightening statements in a very aggressive manner:


"In such a situation, the introduction of genetically engineered (GE) seeds becomes worrisome. In absence of any such regulation, the costlier GE seeds will offer no guarantee for whether they perform well or not. This will lead to complete erosion of the agricultural biodiversity and adversely affect the socio-economic status of the farmers. This will be further aggravated since GE seeds will be patented, and corporations will treat information about them as proprietary."

The best critiques of the activities of Vandana Shiva are published by the following authors:

Conrad-Rossi Marco Rosaire (20140209, DeGregori Tom (20030416, Entine Jon (2014, Entine Jon and Ryan Cami (20140119, Kershon Drew (20140604, Koor Keith (20141023, Miller Henry (20140716, Novella Steven (20150820, Remnick David (20140902, Ryan Cami (20140128, Shiva Vandana (20140824, Specter Michael (20140825)

And another citation from Greenpeace Great Britain, downloaded from their website November 12, 2009 ¹, another classic example of stigmatization with blatantly wrong data:

"The introduction of genetically modified (GM) food and crops has been a disaster. The science of taking genes from one species and inserting them into another was supposed to be a giant leap forward, but instead they pose a serious threat to biodiversity and our own health. In addition, the real reason for their development has not been to end world hunger but to increase the stranglehold multinational biotech companies already have on food production."

The contrary is true, GM crops can help reduce the application of herbicides which are problematic for the environment, and a plethora of hard data proofs that non-target insects often survive quite well in Bt maize fields, whereas in non-GM crop fields, often the non-target organisms suffer from massive spraying of chemicals problematic to the environment and life. Another set of hard facts has been generated from the no-tillage culture of herbicide tolerant soybeans, where it is proven that soil fertility is greatly enhanced.

6. Types of Biodiversity

6.1 Toward a general theory of biodiversity
Pachepsky, Crawford, et al. (2001) show in a thoughtful publication, that there are still many unknowns in the equations modeling biodiversity. They present a framework for studying the dynamics of communities which generalizes the prevailing species-based approach to one based on individuals that are characterized by their physiological traits. The observed form of the abundance distribution and its dependence on richness and disturbance are reproduced, and can be understood in terms of the trade-off between time to reproduction and fecundity.

This is more or less confirmed by Banavar and Maritan (2009) with the following caveat: A lesson from these calculations is that just because a theory fits the data, it does not necessarily imply that the assumptions underlying the theory are correct.

Whereas Pachepsky et al. emphasize the importance of individual organisms over species, Levine and HilleRisLambers (2009) come to the conclusion, that niches play an important role in maintaining biodiversity, together with strong evidence, that species differences have a critical role in stabilizing species diversity. Ecological niches also have been seriously underestimated when calculating with models the impact of climate change on biodiversity: Strikingly enough coexistence of prairie grasses seems to be stabilized with climate variability according to Adler, HilleRisLambers, et al. (2006).

6.2. Genetic diversity and dynamics
In many instances genetic sequences, the basic building blocks of life, encoding functions and proteins are almost identical (highly conserved) across all species. The small un-conserved differences are important, as they often encode the ability to adapt to specific environments. Still, the greatest importance of genetic diversity is probably in the combination of genes within an organism (the genome), the variability in phenotype produced, conferring resilience and survival under selection. Thus, it is widely accepted that natural ecosystems should be managed in a manner that protects the untapped resources of genes within the organisms needed to preserve the resilience of the ecosystem. Much work remains to be done to both characterize genetic diversity and understand how best to protect, preserve, and make wise use of genetic biodiversity Batista, Saibo, et al. (2008, Baum, Bogaert, et al. 2007, Cattivelli, Rizza, et al. 2008, Mallory and Vaucheret 2006, Mattick 2004, Raikhel and Minorsky 2001, Witcombe, Hollington, et al. (2008).

The number of metabolites found in one species exceeds the number of genes involved in their biosynthesis. The concept of one gene - one mRNA - one protein - one product needs modification. There are many more proteins than genes in cells because of post-transcriptional modification. This can partially explain the multitude of living organisms that differ in only a small portion of their genes. It also explains why the number of genes found in the few organisms sequenced is considerably lower than anticipated.

Genomes are subject to many dynamic processes and structural changes as has been previously anticipated: Actually, genomes are highly dynamic and often have been subject to horizontal gene transfer, so the myth that we are dealing with over Centuries long-lasting stability of the genomes of conventional crops is erroneous.

The classic papers on the reasons why genomes are highly dynamic over time: Fedoroff, Schlappi, et al. (1995, Fedoroff Nina (2013, Fedoroff Nina and Jeffrey L. Bennetzen (2013)
Astonishingly, the vast majority of the DNA in higher plants comprises transposons and retrotransposons: 85% of the maize genome, for example, consists of TEs, predominantly retrotransposons. The typical large angiosperm genome exhibits small “islands” of genes in a “sea” of repetitive DNA, primarily consisting of retrotransposons (Chapter 10). Although there is significant constancy of total gene numbers and retention of gene complements, the co-linearity of homologous genes declines with evolutionary distance and intergenic regions change rapidly (Chapter 10). Comparisons even among inbred strains of maize reveal substantial differences in gene organization and even larger differences in both the length of intergenic regions and their content of transposons and retrotransposons (Chapter 10). Whole genome comparisons across species suggest that both the movement of genes and the intergenic churn are caused by transposons and retrotransposons. Whether examining the results of transposition events involving a single transposon (Chapter 3) or viewing the contribution of transposons to the evolution of chromosomes (Chapter 10), the centrality of transposons to contemporary genome organization is inescapable. From Fedoroff Nina (2013)

Consequently, also it is wrong to talk about a new completely artificial dynamics of the genome of GMOs is not meeting the results of numerous genomic analysis throughout the living world: Nester (2015, Voytas and Gao (2014, Yang, Du, et al. (2014, Yang, Nakabayashi, et al. (2014)

And - by all means - human beings are not excluded from such evolutionary dynamics of horizontal gene exchange, see Crisp, Boschetti, et al. (2015):

“Background: A fundamental concept in biology is that heritable material, DNA, is passed from parent to offspring, a process called vertical gene transfer. An alternative mechanism of gene acquisition is through horizontal gene transfer (HGT), which involves movement of genetic material between different species. HGT is well-known in single-celled organisms such as bacteria, but its existence in higher organisms, including animals, is less well established, and is controversial in humans.

Results: We have taken advantage of the recent availability of a sufficient number of high-quality genomes and associated transcriptomes to carry out a detailed examination of HGT in 26 animal species (10 primates, 12 flies and four nematodes) and a simplified analysis in a further 14 vertebrates. Genome-wide comparative and phylogenetic analyses show that HGT in animals typically gives rise to tens or hundreds of active ‘foreign’ genes, largely concerned with metabolism. Our analyses suggest that while fruit flies and nematodes have continued to acquire foreign genes throughout their evolution, humans and other primates have gained relatively few since their common ancestor. We also resolve the controversy surrounding previous evidence of HGT in humans and provide at least 33 new examples of horizontally acquired genes.

Conclusions: We argue that HGT has occurred, and continues to occur, on a previously unsuspected scale in metazoans and is likely to have contributed to biochemical diversification during animal evolution.” From Crisp, Boschetti, et al. (2015)

A scientifically correct comparison also on a physiological level between transgenic and conventional maize crops reveals on both sides impressive variation Li, Ding, et al. (2015).

The conclusion of this summary: these facts of a horizontal exchange represent another nail in the coffin of a purely process oriented biosafety assessment.
6.3. Species diversity

For most practical purposes measuring species biodiversity is the most useful indicator of biodiversity, even though there is no single definition of what is a species. Nevertheless, a species is broadly understood to be a collection of populations that may differ genetically from one another to some extent degree, but whose members are usually able to mate and produce fertile offspring. These genetic differences manifest themselves as differences in morphology, physiology, behaviour and life histories; in other words, genetic characteristics affect expressed characteristics (phenotype). Today, about 1.75 million species have been described and named but the majority remains unknown. The global total might be ten times greater, most being undescribed microorganisms and insects May (1990).

6.4. Ecosystem diversity

At its highest level of organization, biodiversity is characterized as ecosystem diversity, which can be classified in the following three categories:

Natural ecosystems, i.e. ecosystems free of human activities. These are composed of what has been broadly defined as “Native Biodiversity”. It is a matter of debate whether any truly natural ecosystem exists today, as human activity has influenced most regions on earth. It is unclear why so many ecologists seem to classify humans as being “unnatural”.

Semi-natural ecosystems in which human activity is limited. These are important ecosystems that are subject to some level of low intensity human disturbance. These areas are typically adjacent to managed ecosystems.

Managed ecosystems are the third broad classification of ecosystems. Such systems can be managed by humans to varying degrees of intensity from the most intensive, conventional agriculture and urbanized areas, to less intensive systems including some forms of agriculture in emerging economies or sustainably harvested forests.

Beyond simple models of how ecosystems appear to operate, we remain largely ignorant of how ecosystems function, how they might interact with each other, and which ecosystems are critical to the services most vital to life on earth. For example, the forests have a role in water management that is crucial to urban drinking water supply, flood management and even shipping.

Because we know so little about the ecosystems that provide our life-support, we should be cautious and work to preserve the broadest possible range of ecosystems, with the broadest range of species having the greatest spectrum of genetic diversity within the ecosystems. Nevertheless, we know enough about the threat to, and the value of, the main ecosystems to set priorities in conservation and better management. We have not yet learnt enough about the threat to crop biodiversity, other than to construct gene banks, which can only serve as an ultimate ratio – we should not indulge into the illusion that large seed banks could really help to preserve crop biodiversity. The only sustainable way to preserve a high crop diversity, i.e. also as many landraces as possible, is to actively cultivate and breed them further on. This has been clearly demonstrated by the studies of Berthaud and Bellon Bellon and Berthaud (2006, Bellon, Berthaud, et al. (2003, Berthaud (2001) Even here we have much to learn, as the vast majority of the deposits in gene banks are varieties and landraces of the four major crops. The theory behind patterns of general biodiversity related to ecological factors such as productivity is rapidly evolving, but many phenomena are still enigmatic and far from
understood Schlapfer, Pfisterer, et al. (2005, Tilman, Polasky, et al. (2005), as for example why habitats with a high biodiversity are more robust towards invasive alien species.

7. Biodiversity Distribution

7.1. Global Biodiversity Distribution

Biodiversity is not distributed evenly over the planet. Species richness is highest in warmer, wetter, topographically varied, less seasonal and lower elevation areas. There are far more species in total per unit area in temperate regions than in polar ones, and far more again in the tropics than in temperate regions. Latin-America, the Caribbean, the tropical parts of Asia and the Pacific all together host eighty percent of the ecological mega-diversity of the world. An analysis of global biodiversity on a strictly metric basis demonstrates that besides the important rain forest areas there are other hotspots of biodiversity, related to tropical dry forests for example Kier, Mutke, et al. (2005, Kuper, Sommer, et al. (2004, Lughadh, Baillie, et al. (2005).

Within each region, every specific type of ecosystem will support its own unique suite of species, with their diverse genotypes and phenotypes. In numerical terms, global species diversity is concentrated in tropical rain forests and tropical dry forests. Amazon basin rainforests can contain up to nearly three hundred different tree species per hectare and supports the richest (often frugivorous) fish fauna known, with more than 2500 species in the waterways. The sub-montane tropical forests in tropical Asia and South America are considered to be the richest per unit area in animal species in the world. Vareschi (1980).

![Fig. 4 Global biodiversity value: a map showing the distribution of some of the most highly valued terrestrial biodiversity world-wide (mammals, reptiles, amphibians and seed plants), using family-level data for equal-area grid cells, with red for high biodiversity and blue for low biodiversity Williams, Lees, et al. (2003)
7.2. On Centers of Biodiversity and Centers of Crop diversity

Centres of biodiversity are still a controversial matter as was shown by Barthlott, Hostert, et al. (2007) with the example of various African biodiversity patterns published over decades.

Fig. 5 Historical evolution of maps displaying plant species richness patterns in Africa. Apart from the map of Wulff (1935) which indicates the total species richness of the displayed areas, the maps show species richness per standard area of 10,000 km². All maps are inventory-based and to a varying degree rely on expert-opinion. The same legend of ten classes as displayed was applied to all maps, from Barthlott, Hostert, et al. (2007)

Also the definition of centres of crop biodiversity is still debated. Harlan Harlan (1971), in deviation of the classic Vavilov centers Hawkes (1983, Hawkes (1990, Hawkes (1991, Hawkes (1999, Hawkes and Harris (1990, Vavilov (1926, Vavilov (1951, Vavilov (1987, Vavilov (2009), proposed a theory that agriculture originated independently in three different areas and that, in each case, there was a system composed of a center of origin and a noncenter, in which activities of domestication were dispersed over a span of five to ten-thousand kilometers. One system was in the Near East (the Fertile Crescent) with a non-center in Africa; another center includes a north Chinese center and a non-center in Southeast Asia and the south Pacific, with the third system including a Central American center and a South American non-center. He suggests that the centers and the non-centers interacted with each other.

The centers of diversity which Vavilov described were not discrete but overlapped for a number of crops, as regions which have concentrations of variation assessed in terms of recognizable botanical varieties and races. But he also included a complex of properties which include physiological and ecotype characters Williams (1990). This is why the concept of the biodiversity centers underwent later many amendments and enlargements, which resulted among others in the map of Zeven (1998, Zeven and Zhukovsky (1975).
Harlan proposes the theory that agriculture originated independently in three different areas and that, in each case, there was a system composed of a center of origin and a non-center, in which activities of domestication were dispersed over a span of 5000 to 10000 kilometers. One system includes a definable Near East center and a non-center in Africa; another center includes a North Chinese center and a non-center in Southeast Asia and the South Pacific; the third system includes a Mesoamerican center and a South American non-center. There are suggestions that, in each case, the center and the non-center interact with each other. **Crops did not necessarily originate in the centers of their highest diversity (or in any conventional concept of the term), nor did agriculture necessarily develop in a geographical center.**
A recent world map on the centers of biodiversity is more differentiated, it is coming from a new review based on the history of crop domestication and its current perspectives: Larson, Piperno, et al. (2014): new e.g. the Vavilov-Crop Centers in an evolutionary perspective.

Fig. 9 A map depicting likely centers where the domestication of at least one plant or animal took place. Black outlines surround the most widely accepted independent centers of domestication, and sources of major diffusions of domesticates are indicated by arrows. Green and purple regions, respectively, are those where the domestication process took place during the late Pleistocene to early Holocene transition (12,000–8,200 B.P.), and in the middle Holocene (8,200–4,200 B.P.). Brown regions represent areas where, at present, the evidence for domestication is interpreted based upon the presence of domestic forms indigenous to these regions found outside of their native distributions. Letters A–H correspond to those listed in Fig. 2. Additional detail and references associated with each region are found in the SI Text. From Larson, Piperno, et al. (2014).

“Summary: It is difficult to overstate the cultural and biological impacts that the domestication of plants and animals has had on our species. Fundamental questions regarding where, when, and how many times domestication took place have been of primary interest within a wide range of academic disciplines. Within the last two decades, the advent of new archaeological and genetic techniques has revolutionized our understanding of the pattern and process of domestication and agricultural origins that led to our modern way of life. In the spring of 2011, 25 scholars with a central interest in domestication representing the fields of genetics, archaeobotany, zooarchaeology, geoarchaeology, and archaeology met at the National Evolutionary Synthesis Center to discuss recent domestication research progress and identify challenges for the future. In this introduction to the resulting Special Feature, we present the state of the art in the field by discussing what is known about the spatial and temporal patterns of domestication, and controversies surrounding the speed, intentionality, and evolutionary aspects of the domestication process. We then highlight three key challenges for future research. We conclude by arguing that although recent progress has been impressive, the next decade will yield even more substantial insights not only into how domestication took place, but also when and where it did, and where and why it did not.” From Larson, Piperno, et al. (2014)
Fig. 10  A chronological chart listing the regions where, and the time frames over which, key plants and animals were domesticated. The numbers in the black circles represent thousands of years before present. Gray dashed lines represent documented exploitation before domestication or posited as necessary lead-time to domestication. Blue dashed lines represent either the management of plants or animals (including translocation) or predomestication cultivation of plants, neither of which were associated with morphological indications of domestication. Red bars frame the period over which morphological changes associated with domestication are first documented and a short, solid red bar represents the latest time by which domestication occurred. Although early Holocene plant domestication took place independently in both the Old and New Worlds, early Holocene animal domestication was restricted to the Near East. In addition, the majority of plants and animals on this list were domesticated in the middle Holocene. Additional details and references associated with each taxon are found in Table S1. Letters A–H correspond to those found in Fig. 1.

After this, the reader misses the inclusion of Brinjal, a really important crop for SE-Asia, the paradox is that – contrary to the views in India, Brinjal is originating from Africa: Whereas some of the Indian farmers claim Brinjal having originated from their country, new evidence based on thorough genomic analysis has demonstrated that Brinjal as a vegetable has its origin in Africa: Weese and Bohs (2010). This does not mean that no special care can focus on the Indian biodiversity sub-center, but instead of caring about the potential gene flow of a single gene the farmers should care about the excessive use of pesticides when cultivating conventional Brinjal Kumari, Madan, et al. (2002, Mishra, Upadhyay, et al. (2009), for more information see Ammann Klaus (2013).

8. Loss of Biodiversity in general

Despite great efforts on local, national and global level the trend to species loss is still going on in frightening speed. IUCN, Walter K.S., et al. (1997)

Fig. 11 Percentage of threatened Plant Species in IUCN Report 1997, from IUCN, Walter K.S., et al. (1997)

8.1. Species loss will increase, its impact
Pimm and Raven (2000) come to the following conclusion: **Unless there is immediate action to salvage the remaining unprotected hotspot areas, the species losses will more than double.** There is, however, a glimmer of light in this gloomy picture. High densities of small-ranged species make many species vulnerable to extinction. But equally this pattern allows both minds and budgets to be concentrated on the prevention of nature’s untimely end.

Unless the large remaining areas of humid tropical forests are also protected, extinctions of those species that are still wide-ranging should exceed those in the hotspots within a few decades (see Box 1)."

"Applying the species–area relationship to the individual hotspots gives the prediction that 18% of all their species will eventually become extinct if all of the remaining habitats within hotspots were quickly protected (curve c in Box 1). Assuming that the higher-than-average rate of habitat loss in these hotspots continues for another decade until only the areas currently protected remain (curve b in Box 1), these hotspots would eventually lose about 40% of all their species. All of these projections ignore other effects on biodiversity, such as the possibly adverse impact of global warming, and the introduction of alien species, which is a well-documented cause of extinction of native species." From Pimm and Raven (2000)

According to Myers (2003, Myers, Mittermeier, et al. (2000), these areas (hot spots) constitute only a little more than one million square kilometers. Protecting them is necessary, but not sufficient.
A global synthesis reveals biodiversity loss as a major driver of ecosystem change Hooper, Adair, et al. (2012):

"Evidence is mounting that extinctions are altering key processes important to the productivity and sustainability of Earth’s ecosystems Hooper, Chapin, et al. (2005, Loreau, Naeem, et al. 2001, Tilman (1999, Wordle, Bardgett, et al. (2011). Further species loss will accelerate change in ecosystem processes Balvanera, Pfisterer, et al. (2006, Cardinale, Matulich, et al. (2011, Perrings, Naeem, et al. (2011, Stachowicz, Bruno, et al. (2007), but it is unclear how these effects compare to the direct effects of other forms of environmental change that are both driving diversity loss and altering ecosystem function. Here we use a suite of meta-analyses of published data to show that the effects of species loss on productivity and decomposition—two processes important in all ecosystems—are of comparable magnitude to the effects of
many other global environmental changes. In experiments, intermediate levels of species loss (21–40%) reduced plant production by 5–10%, comparable to previously documented effects of ultraviolet radiation and climate warming. Higher levels of extinction (41–60%) had effects rivalling those of ozone, acidification, elevated CO2 and nutrient pollution. At intermediate levels, species loss generally had equal or greater effects on decomposition than did elevated CO2 and nitrogen addition. The identity of species lost also had a large effect on changes in productivity and decomposition, generating a wide range of plausible outcomes for extinction. Despite the need for more studies on interactive effects of diversity loss and environmental changes, our analyses clearly show that the ecosystem consequences of local species loss are as quantitatively significant as the direct effects of several global change stressors that have mobilized major international concern and remediation efforts IPCC, Barker Terry, et al. (2007). From Hooper, Adair, et al. (2012)

Another more recent summary of species loss worldwide has been compiled in 2010 by world-experts – it looks bleak: Butchart, Walpole, et al. (2010), a glance on the major table does not need much explanation:

![Fig. 15 Indicator trends for (A) the state of biodiversity, (B) pressures upon it, (C) responses to address its loss, and (D) the benefits humans derive from it. Data scaled to 1 in 1970 (or for first year of data if >1970), modeled (if >13 data points; see Table 1), and plotted on a logarithmic ordinate axis. Shading shows 95% confidence intervals except where unavailable (i.e., mangrove, seagrass, and forest extent, nitrogen deposition, and biodiversity aid). WBI, Wild Bird Index; WPSI, Waterbird Population Status Index; LPI, Living Planet Index; RLI, Red List Index; IBA, Important Bird Area; AZE, Alliance for Zero Extinction site; IAS, invasive alien species. From Fig. 1 in Butchart, Walpole, et al. (2010)](image-url)

An excellent overview on the biodiversity status of our planet is given by the World Wide Foundation WWF in 2008, but the figures are valid also for projection in the future: WWF, Grooten Monique, et
al. (2012): Clearly, in the light of the below well documented overshoot in footprint, we need urgent measures to be taken, and it is interesting to see, that the WWF is not jumping on the bandwagon of cheap anti-GMO stigmatization. Some years ago this was not yet the case see Thalmann and Kung (2000) including the devastating rebuttal of Janet Carpenter. This rebuttal did astonishingly enough not really have any impact for the follow-up report from 2005 it did not really: World Wildlife Foundation, Assouline Gerald, et al. (200505). Some years later the WWF shifted to a more reasonable position on GMOs: They promote openly White Biotechnology WWF, Novozymes, et al. (2009) and in Agriculture they are instead striving for a holistic picture of the situation.

**Fig. 16 What does “ecological overshoot” mean?**

Humanity’s annual demand on the natural world has exceeded what the Earth can renew in a year since the 1970s. This “ecological overshoot” has continued to grow over the years, reaching a 50 per cent deficit in 2008. This means that it takes 1.5 years for the Earth to regenerate the renewable resources that people use, and absorb the CO2 waste they produce, in that same year. How can this be possible when there is only one Earth? Just as it is possible to withdraw money from a bank account faster than to wait for the interest this money generates, renewable resources can be harvested faster than they can be re-grown. But just like overdrawing from a bank account, eventually the resource will be depleted. At present, people are often able to shift their sourcing when this happens; however at current consumption rates, these sources will eventually run out of resources too—and some ecosystems will collapse even before the resource is completely gone.

The consequences of excess greenhouse gases that cannot be absorbed by vegetation are already being seen, with rising levels of atmospheric CO2 causing increased global temperatures, climate change and ocean acidification. These impacts in turn place additional stresses on biodiversity and ecosystems and the very resources on which people depend. WWF, Grooten Monique, et al. (2012)

It is interesting to see that the WWF is putting “Produce Better” in the center of the synthetic graph of a future perspective:

“WWF’s One Planet perspective explicitly proposes to manage, govern and share natural capital within the Earth’s ecological boundaries. In addition to safeguarding and restoring this natural capital, WWF seeks better choices along the entire system of production and consumption, supported by redirected financial flows and more equitable resource governance. All of this, and more, is required to decouple human development from unsustainable consumption (moving away from material and energy-intensive commodities), to avoid greenhouse gas emissions, to maintain ecosystem integrity, and to promote pro-poor growth and development (Figure 17)”. From WWF, Grooten Monique, et al. (2012)
Fig. 17 One Planet perspective. The center panels reflect better choices for managing, using and sharing natural resources within One Planet limitations and ensuring food, water and energy security. Redirected financial flows and equitable resource governance are essential enabling factors. WWF’S ONE PLANET PERSPECTIVE PROPOSES TO MANAGE, GOVERN AND SHARE NATURAL CAPITAL WITHIN THE EARTH’S ECOLOGICAL BOUNDARIES.
8.2. Agriculture as the major factor of biodiversity loss

Biodiversity is being lost in many parts of the globe, often at a rapid pace. It can be measured by loss of individual species, groups of species or decreases in numbers of individual organisms. In a given location, the loss will often reflect the degradation or destruction of a whole ecosystem. The unchecked rapid growth of any species can have dramatic effects on biodiversity. This is true of weeds, elephants, but especially humans, who being at the top of the chain can control the rate of proliferation of other species, as well as their own, when they put their mind to it.

**Habitat loss** due to the expansion of human urbanisation and the increase in cultivated land surfaces is identified as a main threat to eighty five percent of all species described as being close to extinction. The shift from natural habitats towards agricultural land paralleled population growth, often thoroughly and irreversibly changing habitats and landscapes, especially in the developed world. Many from the developed world are trying to prevent such changes from happening in developing nations, to the consternation of many of inhabitants of the developing world who consider this to be eco-imperialism, promulgated by those unable to correct their own mistakes. A clear decline of biodiversity due to agricultural intensification is documented by Robinson and Sutherland (2002) for the post-war period in Great Britain.

Today, more than half of the human population lives in urban areas, a figure predicted to increase to sixty percent by 2020 when Europe, and the Americas will have more than eighty percent of their population living in urban zones. Five thousand years ago, the amount of agricultural land in the world is believed to have been negligible. Now, arable and permanent cropland covers approximately one and a half billion hectares of land, with some 3.5 billion hectares of additional land classed as permanent pasture. The sum represents approximately 38% of total available land surface of thirteen billion ha according to FAO statistics.

Habitat loss is of particular importance in tropical regions of high biological diversity where at the same time food security and poverty alleviation are key priorities. The advance of the agricultural frontier has led to an overall decline in the world’s forests. While the area of forest in industrialised regions remained fairly unchanged, natural forest cover declined by 8% in developing regions. It is ironical that the most bio-diverse regions are also those of greatest poverty, highest population growth and greatest dependence upon local natural resources. Lee and Jetz (2008)
Fig. 18 Regional Concerns: Relative Importance Given to Environmental Issues by Regions: Although poverty and the growing global population are often targeted as responsible for much of the degradation of the world’s resources, other factors—such as the inefficient use of resources (including those of others), waste generation, pollution from industry, and wasteful consumption patterns—are equally driving us towards an environmental precipice. Fig. 4 indicates the relative importance of environmental issues within and across regions UNEP (1997).

Fig. 19 Regional environmental trends in habitat loss UNEP (1997) reflects trends for the same issues, without depicting the rate of changes in these trends. In many instances, although trends are increasing, the rate of increase over the years has slowed down or was less than the rate of increase in economic growth previously experienced by countries with comparable economic growth. This suggests that several countries are making the transition to a more sustainable environment at a lower level of economic development than industrial countries typically did over the last 50 years. From UNEP (1997).
Fig. 20 Changing priority concerns. As nations develop, different sets of environmental concerns assume priority. Initially, prominence is given to issues associated with poverty alleviation and food security and development—namely, natural resource management to control land degradation, provide an adequate water supply, and protect forests from overexploitation and coastal zones from irreversible degradation. Attention to issues associated with increasing industrialization then follows. Such problems include uncontrolled urbanization and infrastructure development, energy and transport expansion, the increased use of chemicals, and waste production. More affluent societies focus on individual and global health and well-being, the intensity of resource use, heavy reliance on chemicals, and the impact of climate change and ozone destruction, as well as remaining vigilant on the long-term protection needs of natural resources. Figure 3 illustrates the observed progression on environmental priority issues. From UNEP (1997)

The full complexity of factors influencing habitat and species loss is still heavily researched and progress can be expected in the next few years. Two examples may suffice to demonstrate on how intricate the dynamics of habitat and species loss is working: Field, Hawkins, et al. (2009, Kerr and Deguise (2004). There is no doubt that the situation is bleak, and action is needed, action which realistically will be built on difficult decisions on priorities.
Fig. 21 Estimated loss and gain of plant species from 2000 to 2005. It is interesting to see that in highly disturbed regions as Europe, SE-Asia and North America the number of species has even augmented, but no doubt: always on the cost of the indigenous flora. [http://maps.grida.no/go/graphic/estimated-loss-of-plant-species-2000-2005](http://maps.grida.no/go/graphic/estimated-loss-of-plant-species-2000-2005)

Sole and Montoya (2006) demonstrate the dynamics of ecological network meltdown due to habitat loss: “Theory suggests that the response of communities to habitat loss depends on both species characteristics and the extent to which species interact. Larger bodied and rare species are usually the first losers in most ecosystems around the world Purvis and Hector (2000, Woodroffe and Ginsberg (1998). Similarly, food web theory predicts that habitat loss and fragmentation reduces population densities of top predators 13, and therefore species of higher trophic levels are more frequently lost than species from lower levels, see Petchey, Downing, et al. (2004) for a review. In a related context, the consequences of species loss are highly mediated by the position of such species within the interaction network Dunne, Williams, et al. (2002, Pimm 1993, Pimm, Russell, et al. (1995, Sole and Montoya (2001). The disappearance of preys attacked by numerous specialized predators, for example, have larger consequences than the loss of preys with fewer specialized predators.”
Still, more needs to be known about the dynamics of habitat loss Memmott, Alonso, et al. (2006): Habitat destruction is a collective term for a variety of environmental troubles, each of which may have different effects on food web structure and, given that they often act concomitantly, may also interact with each other in unpredictable ways. While a frequent outcome of habitat destruction is species loss, whether the different types of habitat destruction lead to different patterns of species loss remains largely unknown.

### 8.3. Adaptation and other factors compensate for species loss

On a more optimistic note, there are also data available to demonstrate adaptation of threatened species which leads to compensation of population loss:

First it should be stated that we know for some time that thematic resolution matters when studying habitat fragmentation: Bailey, Herzog, et al. (2007):
anticipate that these results will enable a more informed selection of metrics based on an improved knowledge of the effects of thematic resolution.” From Bailey, Herzog, et al. (2007)

It is important to carefully evaluate judgements on landscape, mass flowering and bees (including wild bees), the results can be surprising: mass flowering crops can enhance the life of wild bees, but at the same time it can reduce pollination of adjacent wild flowers: Holzschuh, Dormann, et al. (2013, Holzschuh, Dormann, et al. (2011). This is confirmed by Garibaldi, Steffan-Dewenter, et al. (2013), the multiple author’s findings:

“The diversity and abundance of wild insect pollinators have declined in many agricultural landscapes. Whether such declines reduce crop yields, or are mitigated by managed pollinators such as honey bees, is unclear. We found universally positive associations of fruit set with flower visitation by wild insects in 41 crop systems worldwide. In contrast, fruit set increased significantly with flower visitation by honey bees in only 14% of the systems surveyed. Overall, wild insects pollinated crops more effectively; an increase in wild insect visitation enhanced fruit set by twice as much as an equivalent increase in honey bee visitation. Visititation by wild insects and honey bees promoted fruit set independently, so pollination by managed honey bees supplemented, rather than substituted for, pollination by wild insects. Our results suggest that new practices for integrated management of both honey bees and diverse wild insect assemblages will enhance global crop yields. From Garibaldi, Steffan-Dewenter, et al. (2013)

This is of course a strong argument for grass strip corridors in agricultural landscapes, as promoted by Holzschuh, Steffan-Dewenter, et al. (2009) and Nentwig (1999, Nentwig (2003).

A comprehensive review about Landscape effects on crop pollination services showing a clear pattern:

“Pollination by bees and other animals increases the size, quality, or stability of harvests for 70% of leading global crops. Because native species pollinate many of these crops effectively, conserving habitats for wild pollinators within agricultural landscapes can help maintain pollination services. Using hierarchical Bayesian techniques, we synthesize the results of 23 studies — representing 16 crops on five continents — to estimate the general relationship between pollination services and distance from natural or semi-natural habitats. We find strong exponential declines in both pollinator richness and native visitation rate. Visititation rate declines more steeply, dropping to half of its maximum at 0.6 km from natural habitat, compared to 1.5 km for richness. Evidence of general decline in fruit and seed set — variables that directly affect yields — is less clear. Visititation rate drops more steeply in tropical compared with temperate regions, and slightly more steeply for social compared with solitary bees. Tropical crops pollinated primarily by social bees may therefore be most susceptible to pollination failure from habitat loss. Quantifying these general relationships can help predict consequences of land use change on pollinator communities and crop productivity, and can inform landscape conservation efforts that balance the needs of native species and people.”

From Ricketts, Regetz, et al. (2008).

Despite these differences among studies, syntheses such as those we conduct here remain valuable. Our findings indicate that we can expect declines, on average, in pollinators and crop pollination if further land use change increases the isolation of farms from natural habitat. These declines can be counteracted by conserving areas of natural or semi-natural habitat near farms, by managing farms themselves to support pollinators, or by adding managed pollinators to the landscape. Our consensus decay rates can also serve as parameters for general models of ecosystem service delivery across changing landscapes (Naidoo & Ricketts 2006; Priess et al. 2007). They can inform conservation plans that seek to balance the needs of biodiversity and people, identifying win-win areas where conservation can benefit both, as well as areas of trade off where difficult choices must be made (Chan et al. 2006; Steffan-Dewenter et al. 2007). They can help predict the positive and negative impacts of conservation actions on nearby farmers. And they can inform the design of further experiments and point out research priorities, as we continue to learn about the ecosystem services provided by native pollinators and the habitats that support them.

Fig. 23 Relationship between pollinator richness and isolation from natural habitat. (a) Decay rate (bi ) and 90% credible interval for each study in which pollinator richness was measured (n = 19). Overall decay rate (lb) for all studies is shown at bottom. (b) Richness decay curve, based on overall decay rate and 90% credible interval from panel a. The distance at which richness drops to 50% of the maximum is 1507 m (Table 2). See next page: From Ricketts et al. 2008
9. Crop Biodiversity reduced or not? It depends on how you interpret or manipulate the statistics

According to van de Wouw, van Hintum, et al. (2010) the agricultural crop biodiversity trends are not as negative as common sense would suggest: Although there was a significant reduction of crop biodiversity of 6% in the 1960s compared to 1950, the data indicate that after the 1960s the trend was positively reversed.


In recent years, an increasing number of papers has been published on the genetic diversity trends in crop cultivars released in the last century using a variety of molecular techniques. No clear general trends in diversity have emerged from these studies. Meta analytical techniques, using a study weight adapted for use with diversity indices, were applied to analyze these studies. In the meta-analysis, 44 published papers were used, addressing diversity trends in released crop varieties in the twentieth century for eight different field crops, wheat being the most represented. The meta-analysis demonstrated that overall in the long run no substantial reduction in the regional diversity of crop varieties released by plant breeders has taken place. A significant reduction of 6% in diversity in the 1960s as compared with the diversity in the 1950s was observed. Indications are that after the 1960s and 1970s breeders have been able to again increase the diversity in released varieties. Thus, a gradual narrowing of the genetic base of the varieties released by breeders could not be observed. Separate analyses for wheat and the group of other field crops and separate analyses on the basis of regions all showed similar trends in diversityvan de Wouw, van Hintum, et al. (2010).
Fig. 24 Crop genetic diversity in the twentieth century based on an unweighted (a) and a weighted (b) meta-analysis of 44 publications. The diversity in the decade with the lowest diversity was set to 100, from van de Wouw, van Hintum, et al. (2010)

Fig. 25 Wheat genetic diversity (a) and crop genetic diversity (excluding wheat) (b) in the twentieth century based on a weighted meta-analysis of 20 publications. The diversity in the decade with the lowest diversity was set to 100

“Wheat has been the most popular crop for studies on genetic diversity trends as 421 out of a total of 732 decadal comparisons in this meta-analysis involved wheat. To check whether the wheat studies dominated the final result, two additional analyses were carried out with only the wheat studies and excluding the wheat studies respectively (Fig. 3a, b). Although in these smaller analyses no significant effects could be observed, the general trends were similar, with a low diversity around the 1960s still visible in both cases. The analyses of the wheat studies showed a relatively later, in the 1990s, recovery of the genetic diversity, while the other crops showed this recovery

In a paper the vegetable crop diversity has been put in relation with patents by Heald and Chapman (2009a)

"The intellectual property system does not seem to drive the rate of innovation in the market for vegetable varieties. Drawing on a unique data set of all plant patents, plant variety protection certificates, and utility patents among 42 vegetable varieties, this short paper examines the relationship between intellectual property rights in vegetable crops and the diversity of commercially available varieties. Three findings are of particular interest: 1) Only 3.8% of varieties available in 2004 were ever subject to protection under patent law or the Plant Variety Protection Act; 2) More than 16% of all vegetable varieties that have ever been patented were commercially available in 2004; and 3) In 2004, approximately 4.5% of protected, or once protected, varieties consisted of inventions that were at least twenty years old. Although intellectual property rights appear to be an insignificant part of the crop diversity story, they exhibit much higher commercialization rates than expected (the conventional wisdom suggests a 5% rate), and they exhibit a slower rate of obsolescence than expected. Complete data on individual vegetable types are provided, and the sui generis nature of corn is also discussed." From Heald and Chapman (2009b).

"There are clear diversity winner and losers. Growers of garden beans, garlic, lettuce, peppers, squash, and tomatoes, have many more choices in 2004 than they did in 1903. For beans, the number of varieties increased from 185 to 771, for garlic from 3 to 274, for lettuce from 107 to 520, for peppers from 126 to 674, and for tomatoes from 408 to 1518. On the other hand, growers of beets (only 92 varieties compared to 466), cabbage (81 compared to 544), radishes (138 compared to 463), rutabaga (29 compared to 168), and turnips (38 compared to 237) have vastly fewer choices." p. 32-33 from Heald and Chapman (2011a)

The graph in the National Geographic Magazine is based on an old RAFI study from 1983 with a clearly limited choice of data, today we know with statistics based on comprehensive insight that crop diversity is climbing steadily in numbers as shown above by van de Wouw, van Hintum, et al. (2010). The prepublication of Heald and Chapman (2009b) offers the same picture:

"A complete inventory of all North American commercial seed catalogs undertaken in 1903 and 2004 both reveal around 7000 different varieties offered for sale. Because only a little over 400 of the modern varieties date from 1903 or earlier, the data suggest an impressive amount of innovative activity between 1903 and 2004. About 6500 of the 2004 varieties are twentieth century innovations or imports, suggesting that thousands of other new varieties came and went in the years between 1903 and 2004. What drives the cycle of continuing innovation: patented inventions, unpatented creations, or importation? The data presented herein strongly suggest that the intellectual property system (including the Plant Patent Act, the Plant Variety Protection Act, and utility patents [collectively hereinafter "patents"]) plays an insignificant role in vegetable crop diversity, with the possible exception of corn." Heald and Chapman (2009a)

The table of the data has been published in Heald and Chapman (2009a), separate link under 2.

The publication on a careful account on crop diversity of Heald and Chapman Heald and Chapman (2011a) merits detailed mention: The results clearly contradict the old, unfortunately still persistent RAFI-myth on a catastrophic crop variety loss, the basis of their data and the interpretation is highly questionable.

The authors come to negative conclusions about the quality of the RAFI study, which has penetrated hundreds of websites and is now the common story which needs no citation anymore. But despite its immense popularity, the RAFI study, published in extenso within Fowler and Mooney (1990) contains serious flaws, as described in detail in Heald and Chapman (2011a)

"Our work comparing the varietal availability of the same forty two crops studied by RAFI shows 7218 varieties available in 1903 and 6916 varieties available in 2004. We demonstrate that diversity has been sustained by the addition of thousands of new varieties, undermining the widely accepted diversity erosion thesis. We also find that this varietal replacement is not accomplished via hybridization or patented biotechnology.

Second, the RAFI study itself did not compare apples to apples. The 1903 inventory of commercial catalog Tracy (1903) was compared to the 1983 U.S. government holdings in a seed bank, rather than to an available parallel comprehensive inventory of commercial seed catalogs Whealy (2009). Our comparison of the 1903 commercial seed catalogs with a comprehensive 2004 study of commercial seed catalogs establishes a survival rate for older varieties that is twice the rate reported by Fowler and Mooney. Finally, Fowler and Mooney’s original “shattering” three percent figure is the result of a significant math error that we report for the first

time. They correctly listed in their book the raw numbers collected by RAFI, but somehow mis-added or mis-divided the figures. The error is easily seen by recalculating the survival rate from the numbers they provide. The actual 1983 survival rate in the apples to oranges RAFI study should have been reported as 7.4%.13, from Heald and Chapman (2011a)

The principal reasons for the wrong previous RAFI statistics on dramatic dwindling variety numbers has been found by Heald and Chapman in mainly two factors: Unreal high variety numbers by multiple counting of the same variety (with different names) of the authors of the old seed catalogues, and an equally dramatic underestimation of the number of new varieties. This reduces the loss-figures considerably. A second confirmed result is that the influence of patenting is obviously minimal, with possible exceptions in crops with major breeding process strongly linked to patenting protection, such as soybeans.

The following publication and the clearly erroneous graph from the National Geographic Magazine is a blatant example of bad science journalism with the target to please (and frighten) an ecology-minded clientel: Tomanio (2011). In this publication the old myths of RAFI published by Fowler and Mooney Fowler and Mooney (1990) based on

"Our Dwindling Food Variety
As we’ve come to depend on a handful of commercial varieties of fruits and vegetables, thousands of heirloom varieties have disappeared. It’s hard to know exactly how many have been lost over the past century, but a study conducted in 1983 by the Rural Advancement Foundation International gave a clue to the scope of the problem. It compared USDA listings of seed varieties sold by commercial U.S. seed houses in 1903 with those in the U.S. National Seed Storage Laboratory in 1983. The survey, which included 66 crops, found that about 93 percent of the varieties had gone extinct. More up-to-date studies are needed". From Tomanio (2011)
“The conventional wisdom, as illustrated in the July 2011 issue of National Geographic, Tomanio (2011) still holds that the last century was a disaster for crop diversity.”. Heald and Chapman (author agrees): “In the mainstream media, this position is so entrenched that it no longer merits a citation.”

Recently, RAFl has lowered the earlier claims of a staggering loss of seed biodiversity in the USA to ca. 30% in their proceedings from 2014 Tracy Bill, Sligh Michael, et al. (20140305), but again, the database is not really revealed properly, and most probably, again there are apples with pears compared in the available data material.

The highly complex system of seed developments based on research and breeding over decades and various regions needs further study.

Many people conclude from the fact that huge monocultures are the result of stupendous commercial success of the Roundup-Ready Soybean that there should also be a low number of soybean varieties, this is debunked by the statistics based on real (although incomplete data) published by Tylka (2002), the figure below shows hundreds of nematode resistant soybeans, most of them equipped with herbicide tolerance transgenes. The figure shows, regardless of possible incongruences and inaccuracies in defining varieties an impressive surge towards more varieties of commercialized soybeans.

![Graph](image)

**Fig. 26** Number of maturity group O, I, II, and III SCN-resistant to determine the best varieties for their local conditions. Soy-Bean varieties available to Iowa soybean farmers, 1991–2014, (data unavailable for 1992, 2005, and 2009). From Tylka (2002)

This view is supported also by a detailed analysis by Chen et al. of Chinese and US material of Soybean varieties on the genomic level: It also reveals a stunning growth of the number of nematode resistant varieties Chen, Wang, et al. (2006).

Another boost of Soybean varieties will be created by new hybridization opportunities between two Soybean species Glycine max and tomentella: Singh and Nelson (2015)

**Abstract**

"Key message: This paper describes methods for unlocking genetic treasure from wild perennial Glycine species of Australia for soybean improvement. The genetic resources of the ca. 26 species of the genus Glycine subgenus Glycine have not been exploited to broaden the genetic base of soybean (Glycine max; 2n = 40). The objectives of this study were to develop methods for producing F1, amphidiploid, BC1, BC2, BC3, and fertile soybean plants from crosses of soybean and the genus Glycine subgenus Glycine species, in order to utilize the subgenus Glycine germplasm in soybean breeding. Soybean cultivars were hybridized with six accessions of 78-chromosome G. tomentella as well as one accession each of 40-chromosome G. tomentella, G. argyrea and G. latifolia. They were chosen because they exhibit resistance to soybean rust. We were successful in producing fertile soybean from soybean cv. 'Dwight' and 78-chromosome G. tomentella accession PI 441001, while other hybrids were discontinued either at F1 or amphidiploid stage. The F1 seeds aborted prior to reaching maturity, so developing seeds from 19 to 21 day old pods were cultured aseptically in various media formulations. Seed maturation and multiple embryo generation media were developed. F1 plants with shoots and roots (2n = 59) were transplanted to pots in greenhouse. Amphidiploid (2n = 118) plants were backcrossed to 'Dwight'. BC1 (2n = 79) plants". From Singh and Nelson (2015).

Summary: Together with the above discussed results on soybeans and crop varieties of van de Wouw, van Hintum, et al. (2010) and Heald and Chapman (2009A, Heald and Chapman (2009B, Heald and Chapman (2011B), the myth of dramatically dwindling crop variety numbers due to modern agriculture, in particular due to genetic engineering is thoroughly debunked.

Consequently, biodiversity has been heavily influenced by humans for centuries, and changes in agro-biological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general coupled with bold action is critical in dealing with the loss of biodiversity. High potential to enhance biodiversity considerably can be seen on the level of regional landscapes, as is proposed by Dollaker (2006, Dollaker and Rhodes (2007), and with the help of remote sensing methods it should be possible to plan for a much better biodiversity management in agriculture Mucher, Steinnocher, et al. (2000).

Finally, two excellent reviews from Tom DeGregory should be mentioned here, they get rid of several myths on modern agriculture and biodiversity: DeGregory T. 2003:


And a letter of Tom DeGregory to Robert B. Zoellick


10. Biodiversity within GM crop fields enhanced: Non-target insects are better off.

Preliminary remarks about the extreme Dynamics in Agro-Systems

Agricultural ecosystems can be dynamic in terms of species diversity over time due to management practices. This is often not understood by ecologists who involve themselves in biosafety issues related to transgenics. They still think in ecosystem categories close (or seemingly close) to nature.
Biodiversity in agricultural settings can be considered to be important at a country level in areas where the proportion of land allocated to agriculture is high: Ammann in Wolfenbarger, Andow, et al. (2004). This is the case in continental Europe for example, where 45% of the land is dedicated to arable and permanent crops or permanent pasture. In the UK, this figure is even higher, at 70%. Consequently, biodiversity has been heavily influenced by man for many centuries, and yearly dramatic changes in agro-biological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general, coupled with bold action, is critical in dealing with the loss of biodiversity.

Consequently, biodiversity has been heavily influenced by humans for centuries, and changes in agro-biological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general coupled with bold action is critical in dealing with the loss of biodiversity. High potential to enhance biodiversity considerably can be seen on the level of regional landscapes, as is proposed by Dollaker (2006, Dollaker and Rhodes 2007), and with the help of remote sensing methods it should be possible to plan for a much better biodiversity management in agriculture Mucher, Steinnocher, et al. (2000). It is evident, that modern robotic methods combined with remote or drone sensing needs to be introduced in all agricultural strategies. Chen, Pan, et al. (2014, Gago, Douthe, et al. (2015, Hedley (2015, Rosegrant and Msangi (2014)


11. Farm Practices and its Influence on Biodiversity: a mixed Bag

Let us first make two preliminary remarks about misunderstandings, both leading to a big misunderstanding related to farming and biodiversity: The today globally preferred crops for commodity crop agriculture are all derived from ancestral species with a natural tendency to monoculture – this might change in the future with a better understanding and use of orphan crops: Gressel (2007b)

Preliminary remark 1
**11.1. Nature’s fields: ancient wild crop relatives grew often in monodominant stands**

Species and genetic diversity within any agricultural field will inevitably be more limited than in a natural or semi-natural ecosystem. Surprisingly enough, many of the crops growing in farming systems all over the world have traits of ancestral parents which lived originally in natural monocultures Wood and Lenne (2001). This is after all most probably the reason why our ancestral farmers chose those major crops. There are many examples of natural monocultures, such as the classic stands of Kelp, *Macrocystis pyrifera*, already analyzed by Darwin Darwin (1845), and more relevant to agriculture, it has now been recognized by agro-ecologists that simple, monodominant vegetation exists throughout nature in a wide variety of circumstances. Indeed, Fedoroff and Cohen (1999) reporting Janzen (1998, Janzen (1999) use the term ‘natural monocultures’ in analogy with crops. Such mono-dominant stands may be extensive. As one example out of many, Harlan recorded that for the blue grama grass (*Bouteloua gracilis*): ‘stands are often continuous and cover many thousands of square kilometers of the high plains of central USA.’ It is of utmost importance for the sustainability of agriculture to determine how these extensive, mono-dominant and natural grassland communities persist and when and if we might expect their collapse. More examples are given in Wood & Lenne 1999 Wood and Lenne (1999), here we cite a few more cases. Wild species: *Picea abies, Spartina townsendii, Pteridium aquilinum*, various species of Bamboos, *Arundinaria ssp, Gagnon and Platt* (2008). Also the related *Phragmites communis* grow in large mono-dominant stands, which contain large clones. They renew after some decades over seeds (just like the large tropical Bamboos do in amazingly regular periods), this causes local temporary breakdowns of the populations. Still other ancestral cultivars are cited extensively Wood and Lenne (2001). *Sorghum*, the wild variety *verticilliflorum* is the widest distributed feral complex of the genus, with a broad climatic plasticity, extending almost continuously east of 20° east longitude from the South African coast to 10° north latitude. It overlaps along its northern and northwestern borders with variety *aethiopicum* and var. *arundinaceum*, again hybridizing extensively. It grows over extensive areas of tall grass savannah in the Sudan Wood and Lenne (2001). Typically enough, Ayana, Bekele, et al. (2000) found a remarkably narrow genetic basis for the variety *verticilliflorum* in their analysis. Wild rice: *Oryza coarctata* is reported in Bengal as growing in simple, oligo-diverse pioneer stands of temporarily flooded riverbanks Prain (1903); Harlan ascribed *Oryza* Harlan (1989) to monodominant populations and illustrated harvests from dense stands of wild rice in Africa (*Oryza barthii*, the progenitor of the African cultivated rice, *Oryza glaberrima*). *Oryza barthii* was harvested wild on a massive scale and was a local staple crop across Africa from the southern Sudan to the Atlantic. Grain yields of wild rice stands in Africa and Asia could exceed 0.6 tons per hectare — an indication of the stand density of wild rice Evans (1998).

Botanists and plant collectors have repeatedly and emphatically noted the existence of dense stands of wild relatives of wheat Wood and Lenne (2001). For example, in the Near East, massive stands of wild wheats cover many square kilometers Harlan (1992). Wild einkorn (*Triticum monococcum subsp. boeoticum*) in particular tends to form dense stands, and when harvested, its yields per square meter often match those of cultivated wheat under traditional management Hillmann (1996). Wild Einkorn occurs in massive stands as high as 2000 meters altitude in south-eastern Turkey and Iran Harlan and Zohary (1966). Wild emmer (*Triticum turgidum subsp. dicoccoides*) grows in massive stands in the northeast of Israel, as an annual component of the steppe-like herbaceous vegetation and in the deciduous oak park forest belt of the Near East Nevo (1998). Wild wheat was also recorded to grow in Turkey and Syria in natural, rather pure stands with a density of 300/ m² Anderson (1998).
Preliminary remark 2

11.2. About extreme Dynamics of Agro-Systems
Agricultural ecosystems can be dynamic in terms of species diversity over time due to management practices. This is often not understood by ecologists who involve themselves in biosafety issues related to transgenics. They still think in ecosystem categories close (or seemingly close) to nature. Biodiversity in agricultural settings can be considered to be important at a country level in areas where the proportion of land allocated to agriculture is high: Ammann in Wolfenbarger, Andow, et al. (2004). This is the case in continental Europe for example, where 45% of the land is dedicated to arable and permanent crops or permanent pasture. In the UK, this figure is even higher, at 70%. Consequently, biodiversity has been heavily influenced by man for many centuries, and yearly dramatic changes in agro-biological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general, coupled with bold action, is critical in dealing with the loss of biodiversity.

Consequently, biodiversity has been heavily influenced by humans for centuries, and changes in agro-biological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general coupled with bold action is critical in dealing with the loss of biodiversity. High potential to enhance biodiversity considerably can be seen on the level of regional landscapes, as is proposed by Dollaker (2006, Dollaker and Rhodes (2007), and with the help of remote sensing methods it should be possible to plan for a much better biodiversity management in agriculture Mucher, Steinnocher, et al. (2000). It is evident, that modern robotic methods combined with remote or drone sensing needs to be introduced in all agricultural strategies. Chen, Pan, et al. (2014, Gago, Douthe, et al. (2015, Hedley (2015, Rosegrant and Msangi (2014)

11.3. The Influence of Agriculture on surrounding Biodiversity
The data on biodiversity in and around agricultural fields is a really mixed bag, the answers depend on many external factors from farm practices over climate to landscape structure and surrounding biodiversity levels.

According to Gabriel, Sait, et al. (2010) on-farm biodiversity components depend on farming practices at farm and landscape levels, but also strongly interacts with fine- and coarse-scale variables.


“There is increasing recognition that ecosystems and their services need to be managed in the face of environmental change. However, there is little consensus as to the optimum scale for management. This is particularly acute in the agricultural environment given the level of public investment in agri-environment schemes (AES). Using a novel multiscale hierarchical sampling design, we assess the effect of land use at multiple spatial scales (from location-within-field to regions) on farmland biodiversity. We show that on-farm biodiversity components depend on farming practices (organic vs. conventional) at farm and landscape scales, but this strongly interacts with fine- and coarse-scale variables. Different taxa respond to agricultural practice at different spatial scales and often at multiple spatial scales. Hence, AES need to target multiple spatial scales to maximize effectiveness. Novel policy levers may be needed to encourage multiple land managers within a landscape to adopt schemes that create landscape-level benefits.” Gabriel, Sait, et al. (2010)
From the discussion: Plant species density was much higher in organic fields than in conventional ones (although differences were much lower for margins), and there were additional landscape-level effects but mainly in organic fields. The absence of a landscape effect in conventional cereal fields is due to farmers using more chemicals to suppress weeds within hotspots. Similarly, epigeal arthropods, butterflies (and bumblebees in arable fields) were more abundant in organic farms and hotspots. In contrast, adult hoverflies (Syrphidae) were more common on conventional farms, especially in hotspots, despite their larvae being more common in organic fields. Farmland bird diversity was also higher on conventional farms (except generalist species and corvidae). In general, the conclusions did not fit the common views of clear benefits of organic farming related to biodiversity. In a Times article, Ben Webster, the editor on environment, concluded:

"Birds such as the skylark and lapwing are less likely to be found in organic fields than on conventional farms, according to a study that contradicts claims that organic agriculture is much better for wildlife. It concludes that organic farms produce less than half as much food per hectare as ordinary farms and that the small benefits for certain species from avoiding pesticides and artificial fertilizers are far outweighed by the need to make land more productive to feed a growing population. The research, by the University of Leeds, is another blow to the organic industry, which is already struggling because of..."

\[3\] http://www.ask-force.org/web/Organic/Webster-Study-Spikes-organic-Times-201005.PDF
falling sales and a report from the Food Standards Agency that found that organic food was no healthier than ordinary produce. In organic fields than on conventional farms, according to a study that contradicts claims that organic agriculture is much better for wildlife. It concludes that organic farms produce less than half as much food per hectare as ordinary farms and that the small benefits for certain species from avoiding pesticides and artificial fertilizers are far outweighed by the need to make land more productive to feed a growing population.”

An interesting and balanced view on various agricultural strategies and biodiversity of crops is given by Johns, Powell, et al. (2013), it is one of the rare pleas for collaboration between the notorious enemies.

“Traditional food systems offer a key link between the social and economic resilience of smallholder farmers and pastoralists and the sustainable food and nutrition security of global populations. This paper addresses issues related to socio-cultural diversity and the continuing complex engagement of traditional and modern communities with the plants and animals that sustain them. In light of some of the unhealthful consequences of the ‘nutrition transition’ to globalized modern diets, the authors define and propose a process for a more successful food system transition that balances agro-biodiversity and processed commodities to support diet diversity, health and social equity alongside sustainable economic growth. We review empirical research in support of practice and policy changes in agriculture, economic development and health domains as well as cross-sectoral and community-based innovation. High-value food crops within domestic and global value chains can be an entry point for smallholders’ participation as contributors and beneficiaries of development, while sustainable small farms, as purveyors of environmental and public health services, diversify global options for long-term adaptation in the face of environmental uncertainty.” From Johns, Powell, et al. (2013)

A case study for high-altitude rice in Nepal by Joshi and Witcombe (2003) has demonstrated, that participatory rice breeding can also result in a positive impact on rice landrace diversity. With the exception of two villages, the varietal richness among adopting farmers was either static or increased, and there was an overall increase in allelic diversity. However, this positive picture could change with an unconsiderate introduction of modern traits

A new and comprehensive meta-study Tuck, Winqvist, et al. (2014) results in a view on organic farming with a clearly positive impact on biodiversity, mainly influenced by the fact that the study has a bias on studies done in regions with highly developed industrial agriculture of the West, and – as the meta study states with emphasis, lacks studies from the developing world.


"1. The benefits of organic farming to biodiversity in agricultural landscapes continue to be hotly debated, emphasizing the importance of precisely quantifying the effect of organic vs. conventional farming.
2. We conducted an updated hierarchical meta-analysis of studies that compared biodiversity under organic and conventional farming methods, measured as species richness. We calculated effect sizes for 184 observations garnered from 94 studies, and for each study, we obtained three standardized measures reflecting land-use intensity. We investigated the stability of effect sizes through time, publication bias due to the ‘file drawer’ problem, and consider whether the current literature is representative of global organic farming patterns.
3. On average, organic farming increased species richness by about 30%. This result has been robust over the last 30 years of published studies and shows no sign of diminishing.
4. Organic farming had a greater effect on biodiversity as the percentage of the landscape consisting of arable fields increased, that is, it is higher in intensively farmed regions. The average effect size and the response to agricultural intensification depend on taxonomic group, functional group and crop type.
5. There is some evidence for publication bias in the literature; however, our results are robust to its impact. Current studies are heavily biased towards northern and Western Europe and North America, while other regions with large areas of organic farming remain poorly investigated.
6. Synthesis and applications. Our analysis affirms that organic farming has large positive effects on biodiversity compared with conventional farming, but that the effect size varies with the organism group and crop studied, and is greater in landscapes with higher land-use intensity. Decisions about where to site organic farms to maximize biodiversity will, however, depend on the costs as well as the potential benefits. Current studies have been heavily biased towards agricultural systems in the developed world. We recommend that future studies pay greater attention to other regions, in particular, areas with tropical, subtropical and Mediterranean climates, in which very few studies have been conducted.” From Tuck, Winqvist, et al. (2014)
Also the graphs produce a differentiated picture when comparing on various statistical selection principles the carefully chosen publications.

![Graph](image)

**Fig. 28** The difference in species richness (%) on organic farms, relative to conventional, classified: (a) by functional group (n: decomposers = 19, herbivores = 6, other = 27, pollinators = 21, predators = 49, producers = 62), (b) by organism group (n: arthropods = 89, birds = 17, microbes = 6, plants = 62) and (c) by crop types (n: cereals = 100, grasses = 13, mixed = 40, orchard = 9, unspecified = 6, vegetables = 16). The grand mean is shown in black, accompanied by the black line. The dashed lines show the zero line. 95% credible intervals are calculated from posterior standard errors. From Tuck, Winqvist, et al. (2014).

A new review on agriculture practice and biodiversity with statistically sound and well differentiated conclusions has been published by Amjath-Babu Amjath-Babu and Kaechele (2015):


“The article describes the land use system transition dynamics in selected states in India and discusses its underlying biodiversity impacts and economic driving forces. The concept of system transition is described as a continuum between forests and highly intensive agriculture via different grades of intensification where profit differential is identified as the system transition pressure. In order to operationalize the concept, the article develops land use suitability, input use intensity and farming system diversity indices which are calculated for different agricultural cropping systems in the selected states of India. The results show the apparent decline in land use suitability, reduction in farming system diversity, increase of cultivation intensity, reflecting a reduction in planned and associated agro-biodiversity. The results also show increasing transition pressure to shift from low intensive and high diverse systems to high intensive low diverse systems that represent increasing opportunity cost of conservation of the former systems. A set of policy measures to deflate the transition pressure that can at least retain a threshold of traditional high diversity systems are briefly discussed. The study also outlines further research directions.”

From Amjath-Babu and Kaechele (2015)
Fig. 29 Coefficient of variation and mean of operating profit (for the period 1999–2009) of crops in various states. Source of data: Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops, Government of India. Fig. 3 from Amjath-Babu and Kaechele (2015)

Alain Ratnadass et al. Ratnadass, Fernandes, et al. (2012) demonstrate how complex it will be to enhance biodiversity in future agro-ecological strategies:


"Farmers are facing serious plant protection issues and phyto-sanitary risks, in particular in the tropics. Such issues are food insecurity, lower income in traditional low-input agro-ecosystems, adverse effects of pesticide use on human health and on the environment in intensive systems and export restrictions due to strict regulations on quarantine pests and limits on pesticide residues. To provide more and better food to populations in both the southern and northern hemispheres in a sustainable manner, there is a need for a drastic reduction in pesticide use while keeping crop pest and disease damage under control. This can be achieved by breaking with industrial agriculture and using an agro-ecological approach, whose main pillar is the conservation or introduction of plant diversity in agro-ecosystems. Earlier literature suggest that increasing vegetational biodiversity in agro-ecosystems can reduce the impact of pests and diseases by the following mechanisms: (1) resource dilution and stimulo-deterrent diversion, (2) disruption of the spatial cycle, (3) disruption of the temporal cycle, (4) allelopathy effects, (5) general and specific soil suppressiveness, (6) crop physiological resistance, (7) conservation of natural enemies and facilitation of their action against aerial pests and (8) direct and indirect architectural/physical effects. Here we review the reported examples of such effects on a broad range of pathogens and pests, e.g. insects, mites, myriapods, nematodes, parasitic weeds, fungi, bacteria and viruses across different cropping systems. Our review confirms that it is not necessarily true that vegetational diversification reduces the incidence of pests and diseases. The ability of some pests and pathogens to use a wide range of plants as alternative hosts reservoirs is the main limitation to the suppressive role of this strategy, but all other pathways identified for the control of pests and disease based on plant species diversity (PSD) also have certain limitations. Improving our understanding of the mechanisms involved should enable us to explain how, where and when exceptions to the above principle are likely to occur, with a view to developing sustainable agro-ecosystems based on enhanced ecological processes of pest and disease control by optimized vegetational diversification." From Ratnadass, Fernandes, et al. (2012)
The review of Ratnadass, Fernandes, et al. (2012) [enhanced with more citations by the author] is limited to the interspecific, or “between species”, dimension of vegetational diversification (from now on referred to as “plant species diversity”, PSD), as opposed to its intraspecific, or genetic, dimension. Actually, there are already extensive reviews of the ways intraspecific crop diversity nearly always reduces yield losses caused by pathogens (Smithson and Lenne (1996); Abdelhalim, Finckh, et al. (2014, Bouws and Finckh (2007, Daellenbach, Kerridge, et al. (2005, Doering, Pautasso, et al. (2012, Doering, Vieweger, et al. (2015, Finckh (2008, Finckh, Gacek, et al. (2000, Sharma and Finckh (2008, Wolfe (2000, Zhu, Chen, et al. (2000, Zhu, Wang, et al. (2003; Ngugi et al. 2001; Mundt (2002, Castillo N.P. (2003); Cox, Garrett, et al. (2004)), and sometimes by pests (Bush et al. 1991; Teetes et al. 1994; Johnson et al. 2006). Similarly, although addressed only marginally in the present review, we recognize intraspecific genetic variability in “service” or “companion” plants and the way such genetic variability can influence the effectiveness of pest management. Integrating selected PSD plants in agroecosystems can reduce the impact of pests and diseases via several causal pathways either individually or in combination, namely: (1) pest-suppressing effects via visual and olfactory cues: resource dilution and stimulo-deterrent diversionary effects; (2) disruption of the spatial cycle via non-host effects; (3) a reduction in the inoculum/carry-over population thanks to the absence of a host plant: disruption of the temporal cycle; (4) below-ground bottom-up allelopathic effects; (5) stimulation of specific below-ground antagonists of pests/ pathogens or induction of general soil suppressiveness; (6) physiological resistance due to improved crop nutrition; (7) facilitation of top-down effects on aerial crop pests via natural enemy conservation and (8) direct and indirect architectural effects, including physical barrier effects and microclimate alteration (Fig. 29).

The relative importance of these effects depends on the crop pest/disease/natural enemy complex, e.g. “bottom-up”, i.e. from a lower to a higher trophic level, vs. “top-down”, i.e. from a higher to a lower trophic level, and belowground vs. aerial dispersal processes, the type of PSD and the scale of its implementation and effects, e.g. soil/plant, field, landscape.

An excellent paper about the difficulties on crop diversity assessment is coming from Chellasamy et al. 2016 along Evaluating an ensemble classification approach for crop diversity verification in Danish greening subsidy control:

Beginning in 2015, Danish farmers are obliged to meet specific crop diversification rules based on total land area and number of crops cultivated to be eligible for new greening subsidies. Hence, there is a need for the Danish government to extend their subsidy control system to verify farmers’ declarations to warrant greening payments under the new crop diversification rules. Remote Sensing (RS) technology has been used since 1992 to control farmers’ subsidies in Denmark. However, a proper RS-based approach is yet to be finalised to validate new crop diversity requirements designed for assessing compliance under the recent subsidy scheme (2014–2020). This study uses an ensemble classification approach (proposed by the authors in previous studies) for validating the crop diversity requirements of the new rules. The approach uses a neural network ensemble classification system with bi-temporal (spring and early summer) WorldView-2 imagery (WV2) and includes the following steps: (1) automatic computation of pixel-based prediction probabilities using multiple neural networks; (2) quantification of the classification uncertainty using Endorsement Theory (ET); (3) discrimination of crop pixels and validation of the crop diversification rules at farm level; and (4) identification of farmers who are violating the requirements for greening subsidies. The prediction probabilities are computed by a neural network ensemble supplied with training samples selected automatically using farmers declared parcels (field vectors containing crop information and the field boundary of each crop). Crop discrimination is performed by considering a set of conclusions derived from individual neural networks based on ET. Verification of the diversification rules is performed by incorporating pixel-based classification uncertainty or confidence intervals with the class labels at the farmer level. The proposed approach was tested with WV2 imagery acquired in 2011 for a study area in Vennebjerg, Denmark, containing 132 farmers, 1258 fields, and 18 crops. The classification results obtained show an overall accuracy of 90.2%. The RS-based results suggest that 36 farmers did not follow the crop diversification rules that would qualify for the greening subsidies. When compared to the farmers’ reported crop mixes, irrespective of the rule, the RS results indicate that false crop declarations were made by 8 farmers, covering 15 fields. If the farmers’ reports had been submitted for the new greening subsidies, 3 farmers would have made a false claim; while remaining 5 farmers obey the rules of required crop proportion even though they have submitted the false crop code due to their small holding size. The RS results would have supported 96 farmers for greening subsidy claims, with no instances of suggesting a greening subsidy for a holding that the farmer did not report as meeting the required conditions. These results suggest that the proposed RS based method shows great promise for validating the new greening subsidies in Denmark.”

Fig. 3 from Chellasamy et al. 2016

The fig. 31 below demonstrates the high diversity of fields under surveillance in this study:
Fig. 32 Classification result of the automated ensemble classification approach. White pixels are non-agricultural areas masked by farmers’ parcels. From Fig. 6 of Chellasamy et al. 2016

Fig. 33 Extraction of farmers’ fields that disobey the crop diversification rule based on (a) farmers’ declaration and (b) RS based ensemble classification approach. The fields in purple color are found to be false declaration by the farmers based on the classification result. The green boxes in ‘b’ show the farmers’ field which is identified to disobey the rule according to RS but not in farmers’ declaration. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article). From Fig. 8 of Chellasamy et al. 2016
A paper from Peru shows the influence of ecological and socio-cultural factors influencing crop diversity:


"Background: The Peruvian Andean region is a main center of plant domestication of the world. There, several tuber species were domesticated and the area lodges one of the most important reservoirs of their varieties and wild relatives. It is also the setting of traditional cultures using and conserving them. However, crop genetic erosion has been reported in the region since several decades ago; therefore, understanding factors influencing both loss and maintenance of crop variation is relevant to design conservation policies.

Previous researches have examined factors influencing agrobiodiversity conservation in the region but additional case studies are recognized to be still necessary for a deeper understanding of causes of genetic erosion and for policy design to prevent and remedy it. Our study focused on analyzing (1) variation in richness of traditional varieties of tubers cultivated among households, (2) changes in varieties richness occurred in four consecutive agricultural cycles, and (3) ecological, social, and cultural factors influencing loss and conservation of varieties. Methods: Richness of farmer varieties of tuber species cultivated by 28 peasant households was monitored in communities of Cajamarca and Huánuco, Peru during four consecutive agricultural cycles (from 2001 to 2005). Indepth interviews were conducted with 12 of the households with higher reputation as conservationists, in order to document farmers’ perception of tubers qualities in ecological, social, economic, technological and culinary aspects and how these influence their decisions of conservation priorities. Traditional varieties were identified according to their local names, which were then confronted among farmers and with scientific catalogues in order to identify synonyms. Based on the information documented, indexes of ecological and socio-cultural factors affecting agricultural practices were designed, and their linear correlations and multivariate relations with varieties richness managed per household were analyzed in order to explore factors with higher influence on conservation of crop variation. Results: A total of 1483 and 507 farmer varieties of tuber species were found in the whole sample and period studied in Huánuco and Cajamarca, respectively. Significantly more varieties managed per household per year were recorded in Huánuco (146.39 ± 12.02) than in Cajamarca (44.55 ± 9.26), and marked differences in number of varieties per year were documented among households within each region (78.25 to 246.50 in Huánuco, 7.50 to 144.00 in Cajamarca).

Correlation and multivariate analyses identified that the extent of agricultural area managed by households, cultural identity, practicing of traditional agricultural techniques, and level of self-sufficiency, are meaningful factors influencing higher varieties richness maintained by households. Yield and culinary attributes were considered by people as main features for selecting and deciding which varieties are priorities for conservation. Conclusions: Maintenance and promotion of indigenous Andean culture is crucial for ensuring conservation of both traditional agro-ecological systems and agrobiodiversity. Policies supporting Andean culture (through educational, cultural and economic programs) are therefore directly connected with conservation of traditional farmer varieties. Promotion of seed availability and interchange are effective actions for maintaining and developing diversity, but using and valuing native tubers at regional, national and international levels are fundamental motivations to enhance policies and processes in this direction. From Velasques-Milla D. et al. 2011.

Motivation reasons of farming in those Peruvian regions are most decisive and should be taken into account when planning future enhancement of rural agriculture: Its 1) use of food, 2) good yield, 3) palatability and 4) estetics.

Fig. 34 Frequency of peasants reasons to cultivate different traditional varieties of native potatoes. According to farmers testimonies from Cajamarca and Huánuco (2008). Fig. 6 from Velasques-Milla D. et al. 2011.
12. Introduced and invasive species, a potential threat to biodiversity
Unplanned or poorly planned introduction of non-native (“exotic” or “alien”) species and genetic stocks is a major threat to terrestrial and aquatic biodiversity worldwide. There are hundreds if not thousands of new and foreign genes introduced with trees, shrubs, herbs, microbes and higher and lower animals each year (Kowarik 2005, Sukopp and Sukopp 1993). Many of those organisms sometimes barely survive and can, after years and even many decades of adaptation, begin to be invasive. In the case of exotic tree species in Central Europe, the average lag time has been calculated to about 150 years (Kowarik 2005). This might be misconstrued as increasing biodiversity, but the final effect is sometimes the opposite – even though Landolt (1994) has enumerated after years of inventory work for the town of Zurich some 2000 higher plant species, a majority of which inhabit disturbed and ruderal habitats. Still, in natural biota the introduced species often displace native species such that many native species become extinct or severely limited, such cases are known to be very serious in tropical islands (Ammann 1997, Fowler, Ganeshan, et al. 2000). The role of British colonial gardens around the world have left not only some ornamental parks but also the heritage of problems caused through fostering hybridization between geographically separated species, the introduction of exotic ornamentals of which some became invasive and on the positive side potentially important new cultivars. An important share of alien species originates from agricultural weeds and as a result of constant traffic with commercial seeds and plant materials such as cotton. The agricultural fields all over the worlds are an interesting case for thousands of alien species crossing the continents.

Freshwater habitats worldwide are amongst the most modified by humans, especially in temperate regions. In most areas, introduction of non-native species is the most or second most important activity affecting inland aquatic areas, with significant and often irreversible impacts on biodiversity and ecosystem function. A classic example is the extinction of half to two thirds of the indigenous fish population in Lake Victoria after the introduction of the Nile perch Lates niloticus, a top predator (Schofield and Chapman 1999). Several species of free-floating aquatic plants able to spread by vegetative growth have dispersed widely over the globe and become major pests. Water hyacinth (Eichhornia crassipes) is a notable example in tropical waters as is Anarchis canadensis = Elodea canadensis in temperate waters of the Northern Hemisphere. Fleming et al. 2015 (Fleming, Dibble, et al. 2015) did not find any evidence for Darwin’s naturalization theory, but declare more studies are needed.

13. Biodiversity as a ‘biological insurance’ against ecosystem disturbance
Biodiversity should still act as biological insurance for ecosystem processes, except when mean trophic interaction strength increases strongly with diversity (Thebault and Loreau 2005). The conclusion, which needs to be tested against field studies, is that in tropical environments with a natural high biodiversity the interactions between potentially invasive hybrids of transgenic crops and their wild relatives should be buffered through the complexity of the surrounding ecosystems.
This view is also confirmed by the results of Davis (2003). Taken together, theory and data suggest that compared to inter-trophic interaction and habitat loss, competition from introduced species is not likely to be a common cause of extinctions in long-term resident species at global, meta-community and even most community levels.

There is a widespread view that centers of crop origin should not be touched by modern breeding because these biodiversity treasures are so fragile that these centers should stay free of modern breeding. This is an erroneous opinion, based on the fact that regions of high biodiversity are particularly susceptible to invasive processes, which is wrong. On the contrary, there are studies showing that a high biodiversity means more stability against invasive species, as well as against genetic introgression (Morris, Kareiva, et al. 1994, Tilman, Polasky, et al. 2005, Whitham, Martinsen, et al. 1999). New research has confirmed, that it is not phylogenetic diversity, it is rather species richness which influences grassland ecology and stability of communities: Venail, Gross, et al. (2015) and Lefcheck, Byrnes, et al. (2015).

The introduction of new predators and pathogens has caused well-documented extinctions of long-term resident species, particularly in spatially restricted environments such as islands and lakes. One of the (in)famous cases of an extinction of an endemic rare moth is documented from Hawaii, it has been caused by a failed attempt of biological control (Henneman and Memmott 2001, Howarth 1991). However, there are surprisingly few instances of extinctions of resident species that can be attributed to competition from new species. This suggests either that competition-driven extinctions take longer to occur than those caused by predation or that biological invasions are much more likely to threaten species through inter-trophic than through intra-trophic interactions (Davis 2003). This also fits well with agricultural experience, which builds on much faster ecological processes combined with “exotic” crops which often lack important instruments for rapid spreading.

There is more evidence, that biological invasions, and thus also transgenic hybrids of wild relatives of GMOs with a potentially higher fitness, are depending on a multitude of factors, some now with recent research stepwise identified:

Von Holle and Simberloff (2005) established the first experimental study to demonstrate the primacy of propagule pressure as a determinant of habitat invisibility in comparison with other candidate controlling factors. There is more evidence documented that vegetation structure and diversity has influence on invasion dynamics on various vegetation types (Von Holle, Delcourt, et al. 2003, Von Holle and Simberloff 2004, Weltzin, Muth, et al. 2003).

In a later paper Fridley, Stachowicz, et al. (2007) the same author group makes even clearer statements:

"Given a particular location that is susceptible to recurrent exotic invasion, native species richness can contribute to invasion resistance by means of neighborhood interactions and should be maintained or restored."

See also the caption of the figure from Fridley, Stachowicz, et al. (2007) where a similar statement is included.
Fig. 35 Conceptualized diagram of the invasion paradox. Fine-grained studies, many of which are experimental, often suggest negative correlations between native and exotic species richness but are highly variable. Nearly all broader-grain observational studies indicate positive native–exotic richness correlations. Likely exceptions are comparisons between temperate and tropical biomes, where preliminary data suggest that biodiversity hotspots have very few exotic species. From Fridley, Stachowicz, et al. (2007).

The much more dynamic picture on agricultural fields fits well with farming experience, which builds on much faster ecological processes. It is a widespread error of many ecologists not to take into account the ephemeral ecological situation of agricultural plant communities Ammann, Wolfenbarger, et al. (2004).

Also according to Thebault and Loreau (2005) biodiversity should still act as biological insurance for ecosystem processes, except when mean trophic interaction strength increases strongly with diversity. The conclusion – which needs to be tested against field studies, is that in tropical environments with a natural high biodiversity the interactions between potentially invasive hybrids of transgenic crops and their wild relatives should be buffered through the complexity of the surrounding ecosystems.

This view is also confirmed by Davis (2003): Taken together, theory and data suggest that, compared to inter-trophic interaction and habitat loss, competition from introduced species is not likely to be a common cause of extinctions in long-term resident species at global, meta-community and even most community levels. It should also be clear that the simple introduction of transgenes to the wild populations or any kind of preservable landrace would not cause any harm to biodiversity, except if the introduced transgene is changing the population structure due to some considerable change in the competitiveness of the species or race receiving the transgene. With this caveat it is simply cheap anti-biotech propaganda if one claims that the introgression with transgenes has per se and automatically something to do with a reduction of biodiversity. On the contrary, GMO crops often can – wisely used, be the source of betterment of biodiversity Ammann (2005).

Useful for our thesis produced here is the paper of Morris, Kareiva, et al. (1994). The authors indeed found that barren zones of 4-8 m of in width may actually increase seed contamination over what would be expected if the intervening ground were instead planted entirely with a trap crop.

Finally, it should also be made clear that the threat of landraces is not only caused by environmental and biological agents, but is often the cause of vanishing traditional knowledge Gupta, Sinha, et al.

With enhanced management, maize landraces in Mexico are genetically stable and resistant against gene flow of modern maize traits, including transgenic ones Bellon and Berthaud (2006).

Harlan (1975) was among the first to state that landraces have come to rely on cultivation for their survival, active breeding and conscious selection are at the heart of landrace definition, although not all researchers share this view: Hawkes (1983) states that the adaptation of the landraces to the environment is the result of selection 'largely of an unconscious nature'. An excellent review about definitions and classifications of landraces is given by Zeven (1998), see also Zeven (1999, Zeven (2000, Zeven (2002). An excellent early, but still valid comment and table summing up advantages and disadvantages of ex-situ and in-situ conservation of landraces is given by Hawkes (1991):

"No doubt other factors might be considered in addition to those mentioned in Table I. However, the fact that in-situ and ex-situ methods both possess advantages and disadvantages renders it imperative to scrutinize each with great care. The general conclusions reached up to now are that each method is complimentary to the other, rather than antagonistic. However, the problems continue to confront us, namely, that whereas ex-situ storage methods have been established satisfactorily for at least two decades Frankel and Hawkes (1975) and are those in common use for "orthodox" seeds, those for in-situ conservation are only just beginning to be formulated. This is particularly worrying when we need to decide on conservation strategies for "recalcitrant" species – those whose seeds have no dormancy period and cannot thus be stored under the reduced temperature and humidity that have proved so satisfactory for orthodox species Roberts (1975).

It is quite clear that much more thought and research initiatives need to be applied to the problem of in-situ conservation. The International Board for Plant Genetic Resources, IBPGR (1985) developed a provisional list of species for ecogeographical surveying and in-situ conservation for fruit trees, forages and a number of other crops, and pointed out the need for "sufficiently large and diverse" populations so as to sustain the levels of allelic frequencies in conserved populations. The publication called for further research, setting out at the same time a number of useful parameters for genetic conservation. However, the publication is understandably reticent on hard data involved in setting up reserves, for the simple reason that hard data do not yet exist." Hawkes (1991)

Still, it seems that we do not know yet enough to make out of the above thesis a theory which holds up to all scrutiny, as Ives and Carpenter (2007) develop with convincing details and an impressive survey of the existing literature on biodiversity stability and eco-systems. Their final remarks are rather inconclusive and call for a case-to-case perspective:

"Finally, a finding common to many empirical studies is that the presence of one or a handful of species, rather than the overall diversity of an ecosystem, is often the determinant of stability against different perturbations. We suspect that, depending on the types of stability and perturbation, different species may play key roles. Predicting which species, however, is unlikely to be aided by general theory or surveys of empirical studies; each ecosystem might have to be studied on a case-by-case basis. In the face of this uncertainty and our ignorance of what the future might bring, the safest policy is to preserve as much diversity as possible."

14. Agrobiodiversity and the food web of insects show extreme population dynamics

In a recent and notable paper Macfadyen et al. 2009 Macfadyen, Gibson, et al. (2009), were able to show in extensive field studies, focusing on the food web and its ecosystem services, instead of using traditional biodiversity descriptors, that things are a bit more complex than expected: Although organic farms support greater levels of biodiversity on all three trophic levels, as shown in meta studies Bengtsson, Ahnstrom, et al. (2005, Hole, Perkins, et al. (2005), these systems provide greater levels of natural pest control and therefore also provide greater resistance towards the invasion of alien herbivores since more parasitoids are attacking herbivores. However they also predict Macfadyen, Gibson, et al. (2009), as a consequence of higher species richness, a lower connectance and therefore a lower robustness of organic farms to species loss Lafferty, Allesina, et al. (2008).

It is amazing to see that there are entomologists who wonder about the slightest detail in insect population shifts and food-webs in order to satisfy their strife to find negative effects of transgenic crops on non-target insects, they often forget some basics about experimentation. This has recently happened again with a paper from lab entomologists Lovei, Andow, et al. (2009), which has been refuted justifiably on multiple grounds by an important consortium Shelton, Naranjo, et al. (2009),
here only one important reason mentioned: Feeding experiments have been done in the past Hilbeck, Baumgartner, et al. (1998, Hilbeck, Eckel, et al. (1998) with low quality prey, but when you use healthy prey, the lacewings have a proven extremely high tolerance for the Bt proteins Dutton, Klein, et al. (2002, Romeis, Dutton, et al. (2004). Given here as a typical controversy on experimental details, some of the main influences are completely forgotten: Just imagine the mass extinction effects which happen with certitude, if you change the cropping system, often from year to year? Interestingly enough, there is literature on the detrimental effects of crop rotation against pest insects Landis, Wratten, et al. (2000), but it’s difficult to find field work data on non-target insects related to crop rotation.

15. The case of organic farming, influence on biodiversity and yield comparisons
It is often assumed, that organic farming is automatically helping agrobiodiversity. But is it not that simple. A comparison to conventional farming in Switzerland over 21 years has revealed positive effects of organic farming: Mader, Edenhofer, et al. (2000, Mader, Fliessbach, et al. (2002A, Widmer, Rasche, et al. (2006). Soil fertility, including mycorrhiza data can be related positively to organic farming.

Fact is, that biodiversity depends on many elements, such as landscape, management etc. It is therefore no surprise that biodiversity levels in a comparison between organic and conventional farming show a mixed picture, as demonstrated by Gabriel, Sait, et al. (2010).
Fig. 17 Distribution of different measures describing farmland birds across organic and conventional farms in coldspot (black) and hotspot (grey) landscapes. (g) Ordination of farmland bird species (black dots) and corvids (grey triangles). Means ± SEM per farm and survey, N = 190; number of: (a) farmland bird species, (b) farmland bird specialist species, (c) farmland bird generalist species; (d) Shannon Index; (e) number of farmland birds excluding jackdaw and rook and (f) number of corvids (jackdaw, rook, jay and magpie) per farm and survey. Geometric means are shown for abundance data. The effect of farm management does not depend on which measure is used. See Appendix S1c for additional details. From Gabriel, Sait, et al. (2010)

The authors of the study conclude:

“Conservation management needs to target multiple spatial scales. To date, schemes have been focused on relatively fine scales, because the land is managed at these scales. However, our results suggest that, for maximum effect, there is a need to manage at a spatial scale beyond the farm. The challenge will be to find policy levers to encourage multiple farmers within a landscape to adopt such schemes in concert, thereby creating landscape-level benefits. Our results also have implications beyond agricultural land; wherever wild populations are managed, attention should be paid to the importance of the environment beyond the immediate area of management because this could enhance or detract from the aims of the focal management itself.” Gabriel, Sait, et al. (2010)
This view has been previously confirmed by Weibull, Bengtsson, et al. (2000): The results show clearly, that it is not conventional versus organic farming making the difference in butterfly diversity, it is the specific farm structure:

Fig. 36  a) A principal component analysis of butterfly species composition on 8 organic (circles) and 8 conventional (triangles) farms. PC1 and PC2 together explain 48% of the variation in the data. PC1 is significantly correlated with large-scale heterogeneity ($r_{0.626^{**}}$) and PC2 is significantly correlated with small-scale heterogeneity ($r_{0.669^{**}}$). (n=16). b) The scores of the species included in the principal component analysis. From Weibull, Bengtsson, et al. (2000)

More in detail, the authors also discuss contradictory results: Our results suggest that variation in landscape heterogeneity

"Our results suggest that variation in landscape heterogeneity is more important than the farming system for butterfly diversity and abundance. The general opinion that organic farming enhances diversity is not necessarily true. It is an important conclusion that landscape structure, but not always farming practices, has effects on diversity. Therefore farmers of all kinds should be encouraged to increase the small-scale heterogeneity on their properties to enhance diversity. This can be done with rather simple methods, such as leaving small habitat islands or strips within fields, increasing field margins and open up ditches where possible. Organic farms often have animals and therefore also a certain crop rotation and higher frequency of grazed areas which can be important for species richness. For example, Feber, Firbank, et al. (1997) found a higher butterfly abundance on organic farms compared with conventional farms and suggested that a higher frequency of clover leys on organic farms explained this pattern. In our study we had taken this variation in account when pairing the farms, which might explain why our results are not consistent with those of Feber, Firbank, et al.
On the other hand, yield is still on the negative side in organic farming, as the same DOC 21-year tests in Switzerland have revealed:

The conclusions of the author of this study is tending towards making peace between the various parties of farming management: In order to get out the best possible solutions, always adapted to local conditions, should be an optimal mixture from organic to industrial farming including all methods of modern technology, from better community and landscape structure analysis over enhanced recycling methods to conservation tilling and – last but not least, include modern breeding methods. The author can imagine that some of the transgenic crops (mainly insect resistance and stress resistance events) should be included into ecological and even organic farming. Ammann (2009a, Ammann Klaus and van Montagu Marc (2009, Miller, Morandini, et al. (2008b)).

A recent summary on the failures of organic farming has been published by Iida Ruishalme Ruishalme Iida (20150522) does not shy away from lots of justified criticism but on yield she is a bit too pessimistic as shown by Ponisio, M’Gonigle, et al. (2015) below.

Organic farming up to now does not really produce more yield, as has been shown by many data relevées, a recent meta study published in Nature is also summing up the major literature on this

A particularly interesting case has been published by Lu et al. 2012 Lu, Wu, et al. (2012): Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services:

“On the basis of data from 1990 to 2010 at 36 sites in six provinces of northern China, we show here a marked increase in abundance of three types of generalist arthropod predators (ladybirds, lacewings and spiders) and a decreased abundance of aphid pests associated with widespread adoption of Bt cotton and reduced insecticide sprays in this crop. We also found evidence that the predators might provide additional biocontrol services spilling over from Bt cotton fields onto neighbouring crops (maize, peanut and soybean). Our work extends results from general studies evaluating ecological effects of Bt crops Carriere, Ellers-Kirk, et al. (2003, Gatehouse, Ferry, et al. (2011, Hutchison, Burkness, et al. 2010, Shelton, Zhao, et al. (2002, Wolfenbarger, Naranjo, et al. (2008, Wu, Lu, et al. (2008) by demonstrating that such crops can promote biocontrol services in agricultural landscapes. Lu, Wu, et al. (2012)

A seminal paper has been published 2012, comparing yields in organic and conventional agriculture: Seufert, Ramankutty, et al. (2012). The summary:

“Numerous reports have emphasized the need for major changes in the global food system: agriculture must meet the twin challenge of feeding a growing population, with rising demand for meat and high-calorie diets, while simultaneously minimizing its global environmental impacts Godfray, Beddington, et al. (2010) and Foley, Ramankutty, et al. (2011). Organic farming—a system aimed at producing food with minimal harm to ecosystems, animals or humans—is often proposed as a solution n3,4. However, critics argue that organic agriculture may have lower yields and would therefore need more land to produce the same amount of food as conventional farms, resulting in more widespread deforestation and biodiversity loss, and thus undermining the environmental benefits of organic practices5. Here we use a comprehensive meta-analysis to examine the relative yield performance of organic and conventional farming systems globally. Our analysis of available data shows that, overall, organic yields are typically lower than conventional yields. But these yield differences are highly contextual, depending on system and site characteristics, and range from 5% lower organic yields (rain-fed legumes and perennials on weak acidic to weak-alkaline soils), 13% lower yields (when best organic practices are used), to 34% lower yields (when the conventional and organic systems are most comparable). Under certain conditions—that is, with good management practices, particular crop types and growing conditions—organic systems can thus nearly match conventional yields, whereas under others it at present cannot. To establish organic agriculture as an important tool in sustainable food production, the factors limiting organic yields need to be more fully understood, alongside assessments of the many social, environmental and economic benefits of organic farming systems.”Seufert, Ramankutty, et al. (2012)
Fig. 38 Influence of different crop types, plant types and species on organic-to-conventional yield ratios. a–c, Influence of crop type (a), plant type (b) and crop species (c) on organic-to-conventional yield ratios. Only those crop types and crop species that were represented by at least ten observations and two studies are shown. Values are mean effect sizes with 95% confidence intervals. The number of observations in each class is shown in parentheses. The dotted line indicates the cumulative effect size across all classes. From Seufert, Ramankutty, et al. (2012)

Fig. 39 Sensitivity study of organic-to-conventional yield ratios. Best study quality, peer-reviewed studies using appropriate study design and making appropriate inferences; non-food rotation, studies where both systems have a similar duration of non-food crops; long-term studies, excludes very short duration and recently converted studies; typical conventional, restricted to commercial conventional systems with yields comparable to local averages; comparable systems, studies that use appropriate study design and make appropriate inferences, where both systems have the same non-food rotation length and similar N inputs; best org. management, excludes studies without best management practices or crop rotations; legumes and perennials, restricted to leguminous and perennial crops; best org. performance 1, rain-fed legumes and perennials on weak-acidic to weak-alkaline soils; best org. performance 2, rain-fed and weak-acidic to weak-alkaline soils. Values are mean effect sizes with 95% confidence intervals. The number of observations is shown in parentheses. The dotted line indicates the effect size across all studies. From Seufert, Ramankutty, et al. (2012)
95% credible interval of the yield ratio did not overlap one. Different levels of explanatory variables were considered to influence the amount of N input, soil pH, best management practices, time since conversion to organic management, irrigation and country development. a–f, Influence of the amount of N input (a), soil pH (b), the use of best management practices (BMP; c), time since conversion to organic management (d), irrigation (e) and country development (f) on organic-to-conventional yield ratios. For details on the definition of categorical variables see Supplementary Tables 1–3. Values are mean effect sizes with 95% confidence intervals. The number of observations in each class is shown in parentheses. The dotted line indicates the cumulative effect size across all classes. From Seufert, Ramankutty, et al. (2012)

Some summarizing remarks from Seufert, Ramankutty, et al. (2012) which the author can fully support:

“The results of our meta-analysis differ dramatically from previous results Badgley, Moghtaderi, et al. (2007). Although our organic performance estimate is lower than previously reported in developed countries (~20% compared to ~8%), our results are markedly different in developing countries (~43% compared to ~80%). This is because the previous analysis mainly included yield comparisons from conventional low-input subsistence systems, whereas our data set mainly includes data from high input systems for developing countries. However, the previous study compared subsistence systems to yields that were not truly organic, and/or from surveys of projects that lacked an adequate control. Not a single study comparing organic to subsistence systems met our selection criteria and could be included in the meta-analysis. We cannot, therefore, rule out the claim that organic agriculture can increase yields in smallholder agriculture in developing countries. But owing to a lack of quantitative studies with appropriate controls we do not have sufficient scientific evidence to support it either. Fortunately, the Swiss Research Institute of Organic Agriculture (FiBL) recently established the first long-term comparison of organic and different conventional systems in the tropics Muriuki, Musyoka Martha, et al. (2012). Such well-designed long-term field trials are urgently needed.” Seufert, Ramankutty, et al. (2012)

In a meta-analysis of Lauren Ponisio Ponisio, M’Gonigle, et al. (2015) the yield figures emerge in favor of conventional farming compared to organic practices, but diversification practices on both sides reduce the gap considerably:

“Agriculture today places great strains on biodiversity, soils, water and the atmosphere, and these strains will be exacerbated if current trends in population growth, meat and energy consumption, and food waste continue. Thus, farming systems that are both highly productive and minimize environmental harms are critically needed. How organic agriculture may contribute to world food production has been subject to vigorous debate over the past decade. Here, we revisit this topic comparing organic and conventional yields with a new meta-dataset three times larger than previously used (115 studies containing more than 1000 observations) and a new hierarchical analytical framework that can better account for the heterogeneity and structure in the data. We find organic yields are only 19.2% (+3.7%) lower than conventional yields, a smaller yield gap than previous estimates. More importantly, we find entirely different effects of crop types and management practices on the yield gap compared with previous studies. For example, we found no significant differences in yields for leguminous versus non-leguminous crops, perennials versus annuals or developed versus developing countries. Instead, we found the novel result that two agricultural diversification practices, multi-cropping and crop rotations, substantially reduce the yield gap (to 9 + 4% and 8 + 5%, respectively) when the methods were applied in only organic systems. These promising results, based on robust analysis of a larger meta-dataset, suggest that appropriate investment in agro-ecological research to improve organic management systems could greatly reduce or eliminate the yield gap for some crops or regions.” From Ponisio, M’Gonigle, et al. (2015)

Fig. 40 Influence of N input, soil pH, best management practices, time since conversion to organic management, irrigation and country development. a–f, Influence of the amount of N input (a), soil pH (b), the use of best management practices (BMP; c), time since conversion to organic management (d), irrigation (e) and country development (f) on organic-to-conventional yield ratios. For details on the definition of categorical variables see Supplementary Tables 1–3. Values are mean effect sizes with 95% confidence intervals. The number of observations in each class is shown in parentheses. The dotted line indicates the cumulative effect size across all classes. From Seufert, Ramankutty, et al. (2012)

Fig. 41 The organic-to-conventional yield ratio of (a) all crops, (b,c) plant types and (d) different crop types. Values are mean effect sizes with 95% credible intervals [i.e. 95% of the posterior distribution]. The number of studies and observations in each category are shown in parentheses. Only categories with at least 10 yield comparisons from greater than five studies are shown. Organic and conventional yields were deemed significantly different from each other if the 95% credible interval of the yield ratio did not overlap one. Different levels of explanatory variables were considered to...
be significantly different if the posterior of the difference between the group means did not overlap zero. From Ponisio, M’Gonigle, et al. (2015)

Fig. 42 The influence of (a) cropping system, (b) rotation and (c) nitrogen input on the organic-to-conventional yield ratio. Values are mean effect sizes with 95% credible intervals. The number of studies and observations in each category are shown in parentheses. From Ponisio, M’Gonigle, et al. (2015)

16. Selected proposals for improving high technology agriculture related to biodiversity

16.1. Biodiversity and the management of agricultural landscapes

High potential to enhance biodiversity considerably can be seen on the level of regional landscapes Dollaker (2006, Dollaker and Rhodes (2007), and with the help of remote sensing methods it should be possible to plan for much better biodiversity management in agriculture Mucher, Steinnocher, et al. (2000). This is also a good point for organic farming in marginal regions like the Norwegian Sognefjord. An analysis has shown the positive influence of small scale organic farming in this region Clemetsen and van Laar (2000). Some of the more important papers demonstrate the intensive research activities on the relationship between landscapes and biodiversity Belfrage, Bjorklund, et al. (2005, Boutin, Baril, et al. (2008, Filser, Mebes, et al. (2002, Hendriks, Stobbeelaar, et al. (2000, Jan Stobbelaar and van Mansvelt (2000, Kuiper (2000, MacNaeidhe and Culleton (2000, Norton, Johnson, et al. (2009, Rossi and Nota (2000, Schellhorn, Macfadyen, et al. (2008, Stobbeelaar, Kuiper, et al. (2000). Bawa, Joseph, et al. (2007, Brush and Perales (2007, Harrop (2007, Heywood, Casas, et al. (2007, Jackson, Pascual, et al. (2007A, Jackson, Pascual, et al. (2007B, Pascual and Perrings (2007) all advocate the many ingenious agricultural systems that have shaped novel, resilient landscapes for centuries and in so doing have also sustained high levels of biodiversity. These authors of a special volume for Diversitas also criticize intensification of agriculture with the sole target of enhancing production, and want to go back to traditional management. Unfortunately, traditional agricultural systems are no more compatible with the today’s demand for higher yield and economic incentives. It is therefore essential, to search for innovative combinations of landscape management focusing on biodiversity and modern agriculture. Organo-transgenic strategies have been analyzed in detail and combinations are possible Ammann (2009b, Ammann Klaus (2008b, Ammann Klaus and van Montagu Marc (2009). A bibliography, containing a total of over 300 papers dealing with the impact of ecological agriculture on landscapes and vice versa can be found in Ammann (2009A). There is a lot of potential in restructuring landscape in regions with a high yielding industrial agricultural
production. In a thoughtful multivariate scheme Benton et al. Benton, Vickery, et al. (2003) show the highly complex interactions between farmland activities and the diversity of bird species:

![Figure 19](image)

Fig. 19 The multivariate and interacting nature of farming practices and some of the routes by which farming practice impacts on farmland birds. Arrows indicate known routes by which farming practices (green boxes) indirectly (dark-blue boxes) or directly (light-blue boxes) affect farmland bird demography (yellow boxes), and therefore local population dynamics (orange boxes) and finally total population size (red box). The goal of manipulating farming practice is to impact on population size. Rather than identifying key routes through this web to change in a piece-wise fashion (e.g. insecticide usage), we suggest that management designed to increase habitat heterogeneity is likely to benefit the organisms in such a way as to meet the management goals. The rate at which the birds will feed is determined both by the amount of food (abundance) and its accessibility (access) within the habitat. From Benton, Vickery, et al. (2003).

Now that many of the biodiversity myths related to agriculture are clarified, it is becoming obvious, that one of the priorities in fostering biodiversity in agriculture, is to take better care of the landscape structure, and this is where high tech agriculture can learn from organic and integrated farming. But there are also other ways and means to cope up with the demand of enhancing biodiversity in high tech agriculture.

### 16.2. More biodiversity through mixed cropping

Mixed cropping systems have been proposed for a variety of agricultural management systems. The bibliography coming from the Web of Science reach nearly 300 items and many papers offer a wide variety of options. There is no reason, why modern cropping system with industrial automation could not cope up with some specific mixed cropping systems. Mixed cropping offers advantages in pest management and soil fertility Wolfe (2000, Zhu, Chen, et al. (2000, Zhu, Wang, et al. (2003), but also is subject to limitations, such as the fight against the maize stem borer Songa, Jiang, et al. (2007), still, under low pest pressure a system of maize-bean intercropping in Ethiopia seems to be successful Belay, Schulthess, et al. (2009).

A recent publication confirmed the positive effects: A combination of enhanced AMF (Arbuscular Mycorrhizal Fungi), , EF (Earth Worm data), and mixed cropping increased the yield, mycorrhizal colonization rate, SMB (soil microbial biomass), and nitrogen uptake of the clover plants, confirming
the positive effects of diversity on an agro-ecosystem Zarea, Ghalavand, et al. (2009). Positive results are also reported from Pakistan: A pot experiment was conducted to study the effect of mixed cropping of wheat and chickpea on their growth and nodulation in chickpea Gill, Abid, et al. (2009). But there are also limits to mixed cropping provided you mix crops within the same field without any separation. Paulsen (2007) worked on such intricate mixtures with peas, wheat, lupins, false flax and demonstrated serious problems with reduced yield, those systems need further development.

16.3. On the wish list: more crop diversity, foster orphan crop species.
Another important aspect has been covered by the recently published book of Gressel Gressel (2007) with an interesting theme: a proactive review on orphan crops, their present day deficiencies (the ‘glass ceiling’) and how biotechnology methods could greatly enhance them, so that they could be commercialized in a more competitive way in future. It is especially fascinating to see how the author blends modern molecular biology with a deep insight into agriculture and its forgotten crops. This is an important boundary line, where organic/ecological farming can meet with modern biotechnology and create considerable synergism. Even within crops with a seemingly low reputation like the herbicide tolerant soybeans regarding diversity, trends are positive, as a report from Iowa shows Tylka (2002): Recently there are over 700 nematode resistant soybean traits registered, the majority of them herbicide tolerant.

16.4. Varietal mixture of genes and seeds
Also on a micro scale of seed production, biodiversity could play a new role. Precision Biotechnology could also mean a combination of resistance genes, done either through gene stacking Gressel, Meir, et al. (2007, Lozovaya, Zernova, et al. (2007, Taverniers, Papazova, et al. (2008) or by taking up the idea of artificial gene clusters Thomson, Lafayette, et al. (2002). This has been the accepted strategy up to now. But this goal of introducing more biodiversity in the fields could be achieved in a much simpler way. Other than complex gene-stacking it would be easier to create a seed mix in which each seed contains a single resistance, and the appropriate mixture could be adapted to the local pest situation. This would considerably lower selection pressure Ammann (1999) and would create a situation, which comes closer to nature, where we encounter many genomes within a square mile and dozens of different resistance genes. Varietal mixtures have been proposed by several authors Gold, Altieri, et al. (1989, Gold, Altieri, et al. (1990, Murphy, Campbell, et al. (2007, Smithson and Lenne (1996).

16.5. More biodiversity in the food web including non-target insects by reducing pesticide use with transgenic crops and other strategies

Much has been written on agricultural biodiversity; foremost the book of Wood & Lenne Wood and Lenne (1999) should be mentioned here, a refreshing mix of modern agriculture and independent views on biodiversity. Each chapter, written by some of the best experts in the field, deserves to be taken up in the future debate on agriculture and biodiversity. The chapter on traditional
management written by Thurston, Salick, et al. (1999) provides a very enlightening summary. Of course those management details have to be carefully selected for modern agriculture and where necessary also to be adapted. As a catalogue of ideas the tables in this article serve well.

There are also comparative data available on long term development, with organic and conventional agriculture. The results show positive trends towards more biodiversity, when conventional farms are converted into organic farms, but the influence of local management habits and also a changing landscape are very important Taylor and Morecroft (2009) and high technology farming could again learn.

See the final chapter on case studies for more details.

16.6. Questions about biodiversity and developing countries

This is a big topic with lots of ideas and proposed and/or realized solutions, here only a few examples, first a broad-minded review from international actors: Adenle, Stevens, et al. (2015)

"The twelfth Conference of the Parties for the Convention on Biological Diversity (CBD) meets in the Republic of Korea, 6–17 October 2014. That meeting marks the half-way point for implementation of the decade-long set of targets (the Aichi Targets) agreed at the tenth Conference of the Parties (Nagoya, Japan, October 2010), and poses a real test for the parties. We contend it also offers considerable opportunity to redefine ways and means for funding and awareness raising for the conservation and management of biodiversity, especially in developing countries. Using the adopted, but as-yet poorly implemented, mechanism of National Biodiversity Strategy and Action Plans (NBSAPs) we argue much can be accelerated to ensure that by 2020 the Aichi Targets will have been implemented and that the vision that “by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people” will be within reach. On the other hand, lack or loss of momentum on outreach about, and funding for, biodiversity especially in the global south could see continued declines in the health of ecosystems. From Adenle, Stevens, et al. (2015)

With more emphasis on sustainability, following the same strategy of enhancing biodiversity: Adenle Ademola and Ammann Klaus (2015): They recommend to follow up on 6 items:

1) Re-think and more pro-active debate is needed to resolve GMOs issues whilst its potential as a relevant technological innovation to achieve sustainable development
2) The development and implementation of new policies related to regulation and risk assessment of GMOs in developing countries within the context of consistent international regulatory framework is required as current scope of precautionary principle is controversial and limits the cultivation and trade of GM crops.
3) Encourage innovative farming practices that integrate GM, conventional breeding and organic agriculture to address challenges of sustainable development
4) Identify the most important contributing factors including public investigation and professional long term discourse to the solution of GMO decisions in developing nations. For example, define the role of public, scientists, social scientists and private sector in policy formulation process and implementation.
5) The partnership of national government, UN agencies, NGOs, private sector and other relevant stakeholder group is required in structuring regulatory frameworks
6) While important sustainability issues surrounding GM technology adoption in developing countries requires attention, international movement of GMOs should be governed


Generally, Rob Paarlberg is a clear promoter of modern agriculture in developing countries.
In his last publication on the Ethics of Modern Agriculture his view is differentiated and worth-while to be read: Paarlberg (2009)

"In sum, the ethics of modern agriculture are mixed. On a per-unit-of-production basis, modern agriculture is superior to traditional agriculture in its treatment of both people and the environment, but inferior in its treatment of farm animals. On a per-unit-of-production basis modern agriculture is also superior to organic farming in its treatment of people and the agricultural landscape. Regarding chemical pollution of the environment, modern agriculture is not superior either to traditional agriculture or to organic farming, but pollution trends in modern farming are at least down rather than up per-unit-of-production, thanks to recent moves toward precision farming and thanks as well, in some countries, to the adoption of genetically engineered crops that require fewer chemicals. Why, if this summary is accurate, is modern farming so frequently criticized as somehow less sustainable than either traditional farming or organic farming? The answer to this question requires a much deeper cultural analysis of how attitudes in prosperous countries change, once dietary affluence has been attained (reducing the imperative for still more farm productivity) and once citizens with first hand farming experience shrink in number to constitute less than 5% of the total population. In prosperous modern societies, where few people know farming first hand, citizen misunderstandings regarding the science and economics of agriculture tend to proliferate.” From Paarlberg (2009)

16.7. Proposals adapted to Innovation of Agriculture in Developing Countries.

Push- and pull strategy for reducing pest damage in maize fields

The ‘push-pull’ or ‘stimulo-deterrent diversionary’ strategy is established by exploiting semiochemicals to repel insect pests from the crop (‘push’) and to attract them into trap crops like Desmodium spp. which can at the same time produce with bacterial nodules a nitrogen fertilizer effect. Hassanali, Herren, et al. (2008). Results of this field trial demonstrate higher maize yield when applying the push- and pull strategy, when compared with conventional maize cultures in Africa. It would be more interesting and convincing to see a field trial with a comparison to Bt maize.

In earlier times, Hans Herren was considering an African transgenic Bt maize (2002 at a symposium in Bern), and declared clearly that he is not fundamentally against agricultural biotechnology and under circumstances even would promote GMOs Herren (2003):

“Statement
I have nothing, nor does ICIPE, against the science or principles behind biotechnology, nor for that matter genetic engineering. Both have potential (the former has a proven track record such as tissue culture and marker assisted breeding) in improving agricultural production in the framework of sustainable development. The question I would like to pose is how much and when, for what purpose and under what conditions, at what costs to other agricultural/ biological/ecological disciplines and what can we really expect in the short and medium term.

Background
There has been a tremendous amount of discussion and writing going on the biotechnology/ genetic engineering issues over the past three to four years. Lots of repetition, accusations, polarization and little in term of real scientific progress. This is valid on either side of the issue, as on the one hand the industry is, by nature, pressed to provide marketable products to get return on its investments rather than to concentrate on detailed impact studies. On the other side, the regulatory processes, policy development, impact and deployment research have been left struggling in the desert of ever decreasing overall funding for development cooperation, agricultural research in particular. (P. Pinstrup Andersen and M.J. Cohen, 2000). FAO has taken the lead in opening up the discussion on the positive and negative aspects of Biotechnology as potential to feed an increasing world population (FAO web-page). It clearly states that “Biotechnology, together with other technologies, could provide new solutions to some of the old problems hindering sustainable development and achievement of food security”, I believe that not enough attention is being paid to the words “together with other technologies”, a point made very clear by Dr. Ismoel Serageldin, in Ag biotech and the poor. Although one hears the echo of that sentence everywhere, the actual meaning has been lost.” Herren (2003)

Years later Hans Herren is following a strict anti-GMO course (or maybe a strategy totally ignoring GMOs), as seen in his newsletters of the Biovision organization in Zurich. Herren Hans (2016).

A broad overview of agricultural ecology and the Developing world is summarized in a book chapter by the author: Ammann Klaus (2012): Advancing the course of emerging economies:

The introduction and overview:
The deficit model in teaching is out, science in developing countries shows growing valuable assets, and only dialogue and active listening will unearth mutual understanding between local science and local agriculture. Consequently, there is no room for corporate or environmental imperialism. GM crops have their real chance in developing countries in combination with the genomes of landraces and local modern cultivars - provided those dialogue rules are respected and as a result collaborative breeding programs are implemented which meet the local needs of the farmers and give a chance to make use in African agriculture of top notch science as done by researchers
of the University of Wageningen: Slingerland, Klijn, et al. (2003, Slingerland, Traore, et al. (2006) or in a collaboration between Germany and Namibia Hoffmann, Probst, et al. (2007) To search for a combination of the various agricultural approaches adapted to regional and local needs is the slogan, it’s not about painting contrast by campaigning, teaching and preaching about its own convictions, as done by Marsden Marsden (2012)

The following sections 2-4 describe the premises for a realistic debate on successful bio-economical approaches: (2: science behind modern breeding, 3. high regulatory costs as a direct follow-up of the ‘Genomic Misconception’, 4. concepts of sustainability, from agro-ecology to bio-economy), section 5. will close with three success stories of modern agriculture in developing countries.

16.8. Improvement of conventional breeding

For sure there is also value in the development of conventional breeding methodologies for organic (and non-organic) crops. It is obvious, that also high technology breeding of new crops can learn from the newly developed organic breeding strategies:

In a recent and comprehensive paper, a consortium led by Wolfe Wolfe, Baresel, et al. (2008) give an account on breeding crops for organic farming. Many of the characteristics required in new varieties are common to both conventional and organic agriculture, but there are also a number of breeding targets, mostly of complex nature, that must have a higher priority in organic farming. Characters that are important for the farming system and the crop rotation, weed competition and adaptation to arbuscular mycorrhizas for instance have a higher priority. To rationalize the long enduring selection process, it is necessary to focus on simultaneous selection processes such as weed competition, nutrient uptake and disease/pest resistance. It seems, that the trend to ban any kind of in vitro breeding technology is unfortunately growing and therefore it is anticipated, that banning even marker assisted breeding will deprive the organic community from modern and very efficient tools to achieve the genomic breeding goals. This way, the slowdown process cannot be stopped, it will be very difficult to reach the urgent need of better yield, and the difficulties will grow with the need to cope with a considerably higher diversity of environmental factors, which does not favour centralized breeding. The real force of breeding for organic crops comes from the strong link to social structures, as promoted by a variety of breeding programs, such as the ones on Sorghum in Western Africa by researchers from Wageningen Slingerland, Klijn, et al. (2003, Slingerland, Traore, et al. (2006), explicitly enforcing participative working strategies including traditional knowledge. These thoughts and strategies could well also be taken up by breeding programs using unrestrained all modern DNA related manipulation methods.

16.9. New ways of using biotechnology for enhancing natural resistance of crops

With the pioneering work of Métraux, Boller and Turlings in the mid-eighties and early nineties Metraux and Boller (1986, Metraux, Signer, et al. (1990, Turlings, Tumlinson, et al. (1989) the Systemic Acquired Resistance got some interest: They found that salicylic acid was functioning as internal signal for triggering systemic acquired resistance Dangl and Jones (2001, Metraux, Nawrath, et al. (2002). There is potential for such strategies for fighting off pests by employing mechanisms close to nature.

In 1996, a maize (E)-beta-caryophyllene synthase has been discovered Jackson (1996) implicated in indirect defense responses against herbivores. This defense substance is no more expressed in most American maize varieties, but there is a possibility to restore the defense by genetic engineering Degenhardt, Hiltpold, et al. (2009, Kollner, Held, et al. (2008, Rostas and Turlings (2008) – another promising pathway in modern breeding.
16.10. Final remarks on the improvement list related to biodiversity

This cannot be the place to give a comprehensive list of possible improvements which are compatible with high technology agriculture. This would fill dozens of pages and could also well be the intellectual engine for a long-term research program – and it is rewarding to see that major organizations are active in this field, such as CGIAR, IFPRI etc., including some leading universities such as Cornell, Wageningen, Hohenheim, Davis etc. etc. Rather, the reader is referred to some books having been written with the purpose to improve agricultural biodiversity – most of the chapters cited below do not envisage improving high technology agriculture per se, rather most of the authors see themselves in opposition to it. In the eyes of the author this is at least questionable, and it would be much more fruitful to find opportunities for collaboration and create synergy.

There are a number of books, reports and numerous peer reviewed journal articles which deal with all aspects of ecological agriculture. The authors come with proposals on how to enhance sustainability, how to preserve biodiversity and what can be done so that traditional knowledge with all its treasures does not vanish. There are a majority of authors who really do not lose the focus of the developing world and its dramatic problems, but they avoid topics like modern breeding etc. Altieri and Nicholls (2004, Altieri (2002, Scherr and McNeely (2007, Thurston (1991). Scherr and McNeely Scherr and McNeely (2008) and in particular also Wood & Lenne Wood and Lenne (1999) offer highly interesting chapters on the science and practice of eco-agriculture. It is impressive for the reader to learn about various schemes of integrated farming systems, and some are really integrative and especially strong on the side of analyzing social dynamics, history and economy, topics sometimes forgotten by conservationists and certainly by proponents of high technology agriculture. On the other hand it is striking to see, with a few notable exceptions, that modern breeding technology and in most cases also high technology management methods like remote sensing, GIS supported systems are often only briefly mentioned. In Scherr & McNeely Scherr and McNeely (2007) even a meticulous search does not reveal a single sentence on genetically engineered crops, the otherwise extensive keyword index does not contain such words. On the other hand, it is rewarding to see in the same book a treatment on remote sensing Dushku, Brown, et al. (2007), stating that this is an important instrument in the landscape planning of ecoagriculture (GIS-based decision support). Nevertheless, the scarcity of such treatments provokes the serious question about bias against modern agricultural technology. The same can be said from the IAASTD report. In a rebuttal to a letter to Science Mitchell (2008) attacking the views of Fedoroff Fedoroff (2008), the author Ammann (2008) commented about the IAASTD report IAASTD http://www.agassessment.org/ (2007):

"Mitchell referred to the IAASTD report to degrade the importance of transgenic crops, but this report does not meet scientific review standards and comes to questionable negative conclusions about biotechnology in agriculture: "Information [about GM crops] can be anecdotal and contradictory, and uncertainty on benefits and harms is unavoidable." Such biased judgment ignores thousands of high quality science papers; it is not surprising that most renowned experts left the IAASTD panel before the final report was published".

The good thing about all those cited publications on eco-agriculture is to see with an open mind, that transgenic crops and all high technology practices, including the well tested the first generation transgenic crops, could very well fit into eco-agriculture and, vice versa, that eco-agricultural strategies could very well be introduced into high tech agriculture. The possible positive role of biotechnology related to ecology and conservation has been stated as early as 1996 Bull (1996). It is fact which has been repetitiously stated with solid justification: The present day transgenic crops commercialized are not inherently scale dependent, which means, they can, with some adaptation in the management, very well be integrated in small scale farming – which has been shown with

17. Case studies on the impact of transgenic crops on biodiversity and health
The two case studies are just samples of an intensive biosafety research with thousands of peer reviewed publications, and the positive results from it are well documented. Worldwide, there has not been a single incident of negative, permanent impact of GM crops, published in a peer reviewed journal, which caused real problems in environment and food.

17.1. The case of herbicide tolerant crops, Application of Conservation Tillage easier with herbicide tolerant crops
The soil in a given geographical area has played an important role in determining agricultural practices since the time of the origin of agriculture in the Fertile Crescent of the Middle East. Soil is a precious and finite resource. Soil composition, texture, nutrient levels, acidity, alkalinity and salinity are all determinants of productivity. Agricultural practices can lead to soil degradation and the loss in the ability of a soil to produce crops. Examples of soil degradation include erosion, salinization, nutrient loss and biological deterioration. It has been estimated that 67% of the world’s agricultural soils have been degraded World Resources Institute (2000).

It may also be worth noting that soil fertility is a renewable resource and soil fertility can often be restored within several years of careful crop management.

In many parts of the developed and the developing world tillage of soil is still an essential tool for the control of weeds.

Unfortunately, tillage practices can lead to soil degradation by causing erosion, reducing soil quality and harming biological diversity. Tillage systems can be classified according to how much crop residue is left on the soil surface Fawcett, Christensen, et al. (1994, Fawcett and Towery (2002, Trewavas (2001, Trewawas (2003). Conservation tillage is defined as “any tillage and planting system that covers more than 30% of the soil surface with crop residue, after planting, to reduce soil erosion by water” Fawcett and Towery (2002). The value of reducing tillage was long recognized but the level of weed control a farmer required was viewed as a deterrent for adopting conservation tillage. Once effective herbicides were introduced in the latter half of the 20th century, farmers were able to reduce their dependence on tillage. The development of crop varieties tolerant to herbicides has provided new tools and practices for controlling weeds and has accelerated the adoption of conservation tillage practices and accelerated the adoption of “no-till” practices Fawcett and Towery (2002). Herbicide tolerant cotton has been rapidly adopted since its introduction in Fawcett, Christensen, et al. (1994). In the US, 80% of growers are making fewer tillage passes and 75% are leaving more crop residue Cotton Council (2003). In a farmer survey, seventy-one percent of the growers responded that herbicide tolerant cotton had the greatest impact on soil fertility related to the adoption of reduced tillage or no-till practices Cotton Council (2003). In soybean, the growers of glyphosate tolerant soybean plant higher percentage of their acreage using no-till or reduced tillage practices than growers of conventional soybeans American Soybean Association (2001). Fifty-eight percent of glyphosate-tolerant soybean adopters reported making fewer tillage passes versus five years ago compared to only 20% of non-glyphosate tolerant soybean users American Soybean Association (2001). Fifty four percent of growers cited the introduction of glyphosate tolerant soybeans as the factor which had the greatest impact toward the adoption of reduced tillage or no-
till American Soybean Association (2001). Today, the scientific literature on “no-tillage” and “conservation tillage” has grown on more than 6500 references, a selection of some 1200 references from the last three years are given in the following link: http://www.ask-force.ch/web/Tillage/Bibliography-No-conservation-Tillage-2006-20080626.pdf

Several important reviews have been published in recent months, the all tell a positive story regarding the overall impact of herbicide tolerant crops and the impact on the agricultural environment:

Here just a few examples and statement:

Bonny (2008): In a comprehensive review Bonny describes the unprecedented success of the introduction of transgenic Soybean in the United States.

It is worthwhile to show one of the graphs about the statistics of glyphosate use, thus correcting some of the legends spread by opponents, sometimes coming in seemingly sturdy statistics like those of Benbrook (2004) stating that the herbicide and pesticide use has grown ever since the introduction of transgenic crops. But a closer, more differentiated look reveals this to be an “urban legend”:

Carpenter and Gianessi (2000).

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Fig. 21 Main herbicides used on total soybean acreage, 1990-2006 (as % of soybean surface treated by each herbicide) (From USDA NASS, 1991-2007). With the development of glyphosate-tolerant soybean, this herbicide is used far more extensively. Indeed, it replaces the herbicides used previously; the figure shows only a few of the latter. From Bonny (2008):

“A comparison of transgenic versus conventional soybean reveals that transgenic glyphosate-tolerant soybean allows both the simplification of weed control and greater work flexibility. Cropping transgenic soybean also fits well with conservation tillage. Transgenic soybean has an economic margin similar to conventional soybean, despite a higher seed cost. The next section describes the evolution of the use of herbicides with transgenic soybean, and some issues linked to the rapid increase in the use of glyphosate. At the beginning a smaller amount of herbicides was used, but this amount increased from 2002, though not steadily. Nonetheless, the environmental and toxicological impacts of pesticides do not only depend on the amounts applied. They also depend on the conditions of use and the levels of toxicity and ecotoxicity. The levels of ecotoxicity seem to have somewhat decreased. The success of transgenic soybeans for farmers has led to a higher use of glyphosate as a replacement for other herbicides, which has in turn led to a decline in its effectiveness. However, the issue here is not only genetic engineering in itself, but rather the management and governance of this innovation.”
Cerdeira, Gazziero, et al. (2007) also emphasize the benefits, despite some green propaganda from Brazil and Argentina, but point also to some potential problems with the evolution of glyphosate resistant weeds:

“Transgenic glyphosate-resistant soybeans (GRS) have been commercialized and grown extensively in the Western Hemisphere, including Brazil. Worldwide, several studies have shown that previous and potential effects of glyphosate on contamination of soil, water, and air are minimal, compared to those caused by the herbicides that they replace when GRS are adopted. In the USA and Argentina, the advent of glyphosate-resistant soybeans resulted in a significant shift to reduced- and no-tillage practices, thereby significantly reducing environmental degradation by agriculture. Similar shifts in tillage practiced with GRS might be expected in Brazil. Transgenes encoding glyphosate resistance in soybeans are highly unlikely to be a risk to wild plant species in Brazil. Soybean is almost completely self-pollinated and is a non-native species in Brazil, without wild relatives, making introgression of transgenes from GRS virtually impossible. Probably the highest agricultural risk in adopting GRS in Brazil is related to weed resistance. Weed species in GRS fields have shifted in Brazil to those that can more successfully withstand glyphosate or to those that avoid the time of its application. These include Chamaesyce hirta (erva-de-Santa-Luzia), Convolvulus benghalensis (trapoeraba), Sparrmannia latifolia (erva-quente), Richaradia brasiliensis (poaia-branca), and Ipomoea spp. (corda-de-viola). Four weed species, Conyza bonariensis, Conyza canadensis (buva), Lolium multiflorum (azevem), and Euphorbia heterophylla (amendoim bravo), have evolved resistance to glyphosate in GRS in Brazil and have great potential to become problems.” From Cerdeira, Gazziero, et al. (2007)

These findings are also published in an earlier study with a worldwide scope looking at the herbicide tolerant crops of the Western Hemisphere by some of the same authors Cerdeira and Duke (2006) with the same outcome as above. A summary on glyphosate tolerant crops is also published in Ammann (2004b, Ammann (2005), a recent one still in development: Ammann Klaus (2015)

More pertinent review papers on soil erosion and other agronomic parameters have been published in relationship with the new agricultural management of herbicide tolerant weeds:


17.2. The Case of Impact of Bt maize on non-target organisms

In a study on environmental impact of Bt-maize on the environment, a book project of now 350 pages, the author also has included a commentary chapter for over 180 scientific studies dealing with non-target organism which could be harmed by the cultivation of Bt maize. Observing strictly the baseline comparison with non-Bt maize cultivation, it can be said that there is not a single publication pointing to detrimental effects of Bt maize compared to other maize traits. Four meta-studies have been published recently with more or less stringent selection of data published in scientific journals, and all those meta-analysis do not show any sign of regulatory problems. Chen, Zhao, et al. (2008, Duan, Marvier, et al. (2008, Marvier, McCreedy, et al. (2007, Wolfenbarger, Naranjo, et al. (2008) is singled out here since it is the best meta-analysis existing so far, the selection criteria are clearly defined on all levels and based on a carefully filtered dataset, actually a subset of the database published by Marvier, McCreedy, et al. (2007) on the net under www.sciencemag.org/cgi/content/full/316/5830/1475/DC1

In total, the database used contained 2981 observations from 131 experiments reported in 47 published field studies on cotton, maize and potato. Maize has been studied in the following two comparison categories (including also data on potato and cotton).

- The first set of studies contrasted Bt with non-Bt plots, neither of which received any additional insecticide treatments. This comparison addresses the hypothesis that the toxins
in the Bt plant directly or indirectly affect arthropod abundance. It also can be viewed as a comparison between the Bt crop and its associated unsprayed refuge Gould (2000).

- The second set of studies contrasted unsprayed Bt fields with non-Bt plots that received insecticides. This comparison tests the hypothesis that arthropod abundance is influenced by the method used to control the pest(s) targeted by the Bt crop. (The third set of studies contrasted fields of Bt-crops and non-Bt-crops both treated with insecticides, a category which did not occur in the here included studies of maize.)

Great care was taken to eliminate redundant taxonomic units and multiple development stages of the same species, with a preference of the least mobile development stage, also the datasets are all derived from the same season.

In contrast to the following study by Marvier, McCreedy, et al. (2007) the statistical analysis was not done with the original taxonomic units, rather the authors decided to use an additional descriptor, six ‘functional guilds’ (herbivore, omnivore, predator, parasitoid, detritivores, or mixed). More details can be read in the original publication, as a whole, database robustness and sensitivity of the datasets have been thoroughly discussed and careful decisions have been made in order to get maximum quality of the meta-analysis.

"In maize, analyses revealed a large reduction of parasitoids in Bt fields. This effect stemmed from the lepidopteran-specific maize hybrids, and examining the 116 observations showed that most were conducted on Macrocentrus grandii, a specialist parasitoid of the Bt-target, Ostrinia nubilalis. There was no significant effect on other parasitoids, but M. grandi abundance was severely reduced by Bt maize. Higher numbers of the generalist predator, Coleomegilla maculata, were associated with Bt maize but numbers of other common predatory genera (Orius, Geocoris, Hippodamia, Chrysoperla, were similar in Bt and non-Bt maize." Wolfenbarger, Naranjo, et al. (2008)

The conclusion is rather simple: Bt maize is better for the environment, and in almost all field studies the non-target insects, including a whole range of butterflies have a better survival chance than in non-Bt crop fields.
Fig. 22 The effect of Bt crops on non-target functional guilds compared to unsprayed, non-Bt control fields. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the comparisons (* ,0.05, ** ,0.01, *** ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g001. Fig. 1 from Wolfenbarger, Naranjo, et al. (2008)
The effect of Bt crops on non-target functional guilds compared to insecticide-treated, non-Bt control fields. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the studies (**, 0.05, ***, 0.01, ****, 0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g002. Fig. 2 from Wolfenbarger, Naranjo, et al. (2008)

“In maize, the abundance of predators and members of the mixed functional guild were higher in Bt maize compared to insecticide-sprayed controls (Fig. 2b). Significant heterogeneity occurred in predators, indicating variation in the effects of Bt maize on this guild. For example, we detected no significant effect sizes for the common predator genera Coleomegilla, Hippodamia, or Chrysoperla, but the predator Orius spp. and the parasitoid Macrocentrus were more abundant in Bt maize than in non-Bt maize plots treated with insecticides. Partitioning by taxonomic groupings or the target toxin (Lepidoptera versus Coleoptera) did not reduce heterogeneity within predators. However, insecticides differentially affected predator populations. Specifically, application of the pyrethroid insecticides lambda-cyhalothrin, cyfluthrin, and bifenthrin in non-Bt control fields resulted in comparatively fewer predators within these treated control plots. Omitting studies involving these pyrethroids revealed a much smaller and homogeneous effect size. Predator abundance in Bt fields was still significantly higher compared with insecticide-treated plots, but the difference was less marked without the pyrethroids (Fig. 3). Compared to the subset of controls using pyrethroids, Bt maize was particularly favorable to Orius spp.”
Fig. 24 Effects of Bt maize vs. control fields treated with a pyrethroid insecticide on predatory arthropods. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the studies (* ,0.05, ** ,0.01, *** ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g003 . Fig. 3 from Wolfenbarger, Naranjo, et al. (2008)

"Bt-maize favored non-target herbivore populations relative to insecticide-treated controls, but there was also significant heterogeneity, some of which was explained by taxonomy. Aphididae were more abundant in insecticide sprayed fields and Cicadellidae occurred in higher abundance in the Bt maize in contrast to patterns associated with predators and detritivores, type of insecticide did not explain the heterogeneity in herbivore responses. The pyrethroid-treated controls accounted for 85% of the herbivore records. Individual pyrethroids had variable effects on this group, and none yielded strong effects on the herbivores. An underlying factor associated with the heterogeneity of the herbivore guild remained unidentified, but many possible factors were eliminated (e.g., Cry protein target, Cry protein, event, plot size, study duration, pesticide class, mechanism of pesticide delivery, sample method, and sample frequency). An underlying factor associated with the heterogeneity of the herbivore guild remained unidentified, but many possible factors were eliminated."
As a whole, the study of Wolfenbarger, Naranjo, et al. (2008) did not reveal any negative effects, confirming for a large amount of data and publications the environmental benefits of the Bt maize tested.

**17.3. Biodiversity data in GM crops other than Bt resistance and Herbicide tolerance**

Although one has to see that most commercialized GM crops are related to Bt resistance and herbicide tolerance, there are field data existing for not yet commercialized crops showing likewise positive results, a few examples of transgenic wheat are presented here:
In a study by von Burg, van Veen, et al. (2011), hypothesizing that GM wheat could influence the quantitative food web of aphids, the results suggest that the effects are negligible and the potential effect on non-target insects is limited:

“In this study, von Burg, van Veen, et al. (2011) looked at transgenic disease-resistant wheat (Triticum aestivum) and its effect on aphid–parasitoid food webs. They hypothesized that the GM of the wheat lines directly or indirectly affect aphids and that these effects cascade up to change the structure of the associated food webs. Over 2 years, they studied different experimental wheat lines under semi-field conditions. They constructed quantitative food webs to compare their properties on GM lines with the properties on corresponding non-transgenic controls. They found significant effects of the different wheat lines on insect community structure up to the fourth trophic level. However, the observed effects were inconsistent between study years and the variation between wheat varieties was as big as between GM plants and their controls. This suggests that the impact of our powdery mildew-resistant GM wheat plants on food web structure may be negligible and potential ecological effects on non-target insects limited.” von Burg, van Veen, et al. (2011)

In a previous detailed laboratory study von Burg, Müller, et al. (2010) emphasized that studies of plant–insect interactions and their ecology are important to understand how these interactions shape insect herbivore communities. The use of transgenic plants opens up a whole range of new research questions, which are not necessarily questions about potential environmental risks of the novel plants Raybould (2010). In this study they wanted to find out if and how transgenic powdery mildew-resistant wheat affects the non-target aphid M. dirhodum and whether there are aphid clone x wheat lines (G x E) interactions. The research group could not detect any major effects of the transformed wheat line on a range of life-history parameters in this detailed laboratory study. This suggests that the genetic transformation did not alter the quality of the wheat plants as hosts for the aphid M. dirhodum.

In another study within the same research project (see www.wheat-cluster.ch) came to interesting conclusions, which might be related to epigenetic effects: Abstract:

“Background:
The introduction of transgenes into plants may cause unintended phenotypic effects which could have an impact on the plant itself and the environment. Little is published in the scientific literature about the interrelation of environmental factors and possible unintended effects in genetically modified (GM) plants.

Methods and Findings:
We studied transgenic bread wheat Triticum aestivum lines expressing the wheat Pm3b gene against the fungus powdery mildew Blumeria graminis f.sp. tritici. Four independent offspring pairs, each consisting of a GM line and its corresponding non-GM control line, were grown under different soil nutrient conditions and with and without fungicide treatment in the glasshouse. Furthermore, we performed a field experiment with a similar design to validate our glasshouse results. The transgene increased the resistance to powdery mildew in all environments. However, GM plants reacted sensitive to fungicide spraying in the glasshouse. Without fungicide treatment, in the glasshouse GM lines had increased vegetative biomass and seed number and a twofold yield compared with control lines. In the field these results were reversed. Fertilization generally increased GM/control differences in the glasshouse but not in the field. Two of four GM lines showed up to 56% yield reduction and a 40-fold increase of infection with ergot disease Claviceps purpurea compared with their control lines in the field experiment; one GM line was very similar to its control.

Conclusions:
Our results demonstrate that, depending on the insertion event, a particular transgene can have large effects on the entire phenotype of a plant and that these effects can sometimes be reversed when plants are moved from the glasshouse to the field. However, it remains unclear which mechanisms underlie these effects and how they may affect concepts in molecular plant breeding and plant evolutionary ecology.” Zeller, Kalinina, et al. (2010)

Comment: It is normal, that breeding effects, whether with traditional methods or molecular methods, show differences in reproduction, greenhouse and field performance, this is known by professional breeders and is usually subject to careful selection processes. It is also normal, that many of those effects are unknown in their origin, and the rule is that molecular breeding yields more clarity than conventional methods Muurinen, Slaf er, et al. (2006).

17.4. Bt-corn has less cancer causing mycotoxins than conventional corn
Bt corn is definitely healthier: Many publications have demonstrated that Bt maize has less mycotoxins with their bad reputation of cancerogeneity.
In a worldwide review, Placinta, D’Mello, et al. (1999) summarized the situation on mycotoxins in animal feed (including a comprehensive list of literature).

“Three classes of Fusarium mycotoxins may be considered to be of particular importance in animal health and productivity. Within the trichothecene group, deoxynivalenol (DON) is widely associated with feed rejection in pigs, while T-2 toxin can precipitate reproductive disturbances in sows.

Another group comprising zearalenone (ZEN) and its derivatives is endowed with oestrogenic properties.

The third category includes the fumonisins which have been linked with specific toxicity syndromes such as equine leukoencephalomalacia (ELEM) and porcine pulmonary oedema.”

It is important to know that storage conditions are heavily influencing the fumonisin content of the maize cobs, as was shown by Fandohan, Hell, et al. (2003, Gressel, Hanafi, et al. (2004, Olakojo and Akinlosotu (2004) in Africa: the storage conditions are often poor and foster fungal infection dramatically, also due to post-harvest weevils.

It seems logical to fight fumonisin producing fungi with fungicides, but this is obviously not an easy task according to D’Mello, Macdonald, et al. (1998, D’Mello, Macdonald, et al. (2001, D’Mello, Placinta, et al. (1999). There are no feasible solutions ready – except the ones offered by the Bt crops. Also the use of fungicide sprays does not really bring considerable remedy. It is interesting to note that D’Mello et al. deem most promising to develop Fusarium resistant crops, in order to avoid the clearly detrimental effects of pigs reacting on high fumonisin levels in feed.

Many studies in epidemiological human medicine have proven the clear pathogenicity of fumonisins: Here the important critical review of many pertinent papers: Marasas, Riley, et al. (2004). They found and cite numerous studies which demonstrate that fumonisins are potential risk factors for neural tube defects, craniofacial anomalies, and other birth defects arising from neural crest cells because of their apparent interference with folate utilization.

A slide from Bojin Bojinov from Plovdiv Bulgaria, demonstrated in a conference on GMO regulation in Brussels at the occasion of a meeting with the EU authorities, organized by PRRI and CopaCogeca in March 2015 summarizes well the facts:
Evidently, the conventional maize should no-more get approval due to clear health reasons of the high mycotoxin level. Several mycotoxins are proven cancer causing side products of the fungi infecting the conventional maize (due to the much higher perforations caused by pest insects). Instead, for clear health reasons, the Bt-maize should be globally introduced with a system of patent exemptions as done with the Golden Rice.

18. Some closing words:
Agriculture is in the centre of this text, and rightly so, since we have the urgent task to feed a billion hungry people, and there is no time for sterile sophisticated bickering on whether some hypothetical negative effects could emerge decades from now, since by then, hundreds of millions of people will die from hunger and diseases. The case of the golden rice is symbolic for the situation of mankind: we can develop it as fast as we can, unhampered by over-regulation – or we may tolerate hundreds of thousands of children dying every year from pro-vitamin A deficiency. It is no coincidence that this article closes with some references essential for the Golden Rice debate Depee, West, et al. (1995, Humphrey, Agoestina, et al. (1998, Humphrey, West, et al. (1992, Mayer, Pfeiffer, et al. (2008, Miller (2009A, Potrykus (2003, Stein, Sachdev, et al. (2008). Actually the solution would be extremely simple and its unconditional support would honor all institutions of the United Nations, including the Convention of Biodiversity which has created the Cartagena Protocol on Biosafety.

Human beings should be part of any risk assessment in technology: this is a request with enormous ethical implications.
20 Cited Literature


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