Biodiversity and GM crops

Klaus Ammann, Delft University of Technology

Chapter in
N Ferry and A M R Gatehouse (Editors)
Environmental Impact of Genetically Modified/Novel Crops Aug. 2008 in print

1. 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, but crop biodiversity, the subject of this book, is rarely considered. The author's important contribution to the discussion of crop biodiversity in this volume 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 more scarce. The relationships between biodiversity and ecological parameters, linking the value of biodiversity to human activities are partially summarized in Table 1.

Table 1 Primary goods and services provided by ecosystems

Ecosystem	Goods	Services
Agroecosystems	Food crops Fiber crops Crop genetic resources	Maintain limited watershed functions (infiltration, flow control, partial soil protection) Provide habitat for birds, pollinators, soil organisms important to agriculture Build soil organic matter Sequester atmospheric carbon Provide employment
Forest ecosystems	Timber Fuelwood Drinking and irrigation water Fodder Nontimber products (vines, bamboos, leaves, etc.) Food (honey, mushrooms, fruit, and other edible plants; game) Genetic resources	Remove air pollutants, emit oxygen Cycle nutrients Maintain array of water shed functions (infiltration, purification, flow control, soil stabilization) Maintain biodiversity Sequester atmospheric carbon Generate soil Provide employment Provide human and wildlife habitat Contribute aesthetic beauty and provide recreation
Freshwater ecosystems	Drinking and irrigation water Fish Hydroelectricity Genetic resources	Buffer water flow (control timing and volume) Dilute and carry away wastes Cycle nutrients Maintain biodiversity Sequester atmospheric carbon Provide aquatic habitat Provide transportation corridor Provide employment Contribute aesthetic beauty and provide recreation
Grassland ecosystems	Livestock (food, game, hides, fiber) Drinking and irrigation water Genetic resources	Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) Cycle nutrients Remove air pollutants, emit oxygen Maintain biodiversity Generate soil Sequester atmospheric carbon Provide human and wildlife habitat Provide employment Contribute aesthetic beauty and provide recreation
Coastal and marine ecosystems	Fish and shellfish Fishmeal (animal feed) Seaweeds (for food and industrial use) Salt Genetic resources Petroleum, minerals	Moderate storm impacts (mangroves; barrier islands) Provide wildlife (marine and terrestrial) habitat Maintain biodiversity Dilute and treat wastes Sequester atmospheric carbon Provide harbors and transportation routes Provide human and wildlife habitat Provide employment Contribute aesthetic beauty and provide recreation
Desert ecosystems	Limited grazing, hunting Limited fuelwood Genetic resources Petroleum, minerals	Sequester atmospheric carbon Maintain biodiversity Provide human and wildlife habitat Provide employment Contribute aesthetic beauty and provide recreation
Urban ecosystems	space	Provide housing and employment Provide transportation routes Contribute aesthetic beauty and provide recreation Maintain biodiversity Contribute aesthetic beauty and provide recreation

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 agroecosystem biodiversity vs. total biodiversity (Purvis & 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 facettes, 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 many publications, here a small selection: (Attaran & Maharaj, 2000; Attaran et al., 2000; Curtis, 2002; Curtis & Lines, 2000; Horton, 2000; Roberts et al., 2000; Smith, 2000; Taverne, 1999; Tren & Bate, 2001; WHO, 2005)

Types, distribution, and loss of biodiversity

Genetic diversity

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 unconserved 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 et al., 2008; Baum et al., 2007; Cattivelli et al., 2008; Mallory & Vaucheret, 2006; Mattick, 2004; Raikhel & Minorsky, 2001; Witcombe 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.

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).

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 seedbanks 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 furtheron. This has been clearly demonstrated by the studies of Berthaud and Bellon (Bellon & Berthaud, 2004, 2006; Bellon 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 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 et al., 2005; Tilman et al., 2005), as for example why habitats with a high biodiversity are more robust towards invasive alien species.

The global distribution of biodiversity

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 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 et al., 2005; Kuper et al., 2004; Lughadha 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 submontane 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).

The case of agro-biodiversity

Species and genetic diversity within any agricultural field will inevitably be more limited than in a natural or semi-natural ecosystem. Many of the crops growing in farming systems all over the world have surprisingly enough ancestral parent traits which lived in originally in natural monocultures (Wood & Lenne, 2001). This is after all most probably the reason why our ancestral farmers have chosen those major crops. There are many examples of natural monocultures, such as the classic stands of Kelp, *Macrocystis pyrifera*, already analysed by (Darwin, 1845), and more relevant to agriculture: It has now been recognized by ecologists that simple, monodominant vegetation exists throughout nature in a wide variety of circumstances. Indeed, (Fedoroff & Cohen, 1999) reporting (Janzen, 1998, 1999) use the term ‘natural monocultures’ in analogy with crops. Monodominant stands may be extensive. As one example 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 the utmost importance for the sustainability of agriculture to determine how these extensive, monodominant and natural grassland communities persist when we might expect their collapse. More examples are given in (Wood & Lenne, 1999), here only a few more cases: Wild species: *Picea abies*, *Spartina townsendii*, various species of Bamboos, *Arundinaria ssp, (Gagnon & Platt, 2008), Sorghum verticilliflorum*, *Phragmites communis*, and *Pteridium aquilinum*. Ancestral cultivars are cited extensively by (Wood & Lenne, 2001): Wild rice: *Oryza coarctata*, reported in Bengal as simple, oligodiverse pioneer stands of temporarily flooded riverbanks (Prain, 1903), Harlan described *Oryza* (Harlan, 1989) 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 across Africa from the southern Sudan to the Atlantic. (Evans, 1998) reported that the grain yields of wild rice stands in Africa and Asia could exceed 0.6 tonnes per hectare — an indication of the stand density of wild rice.

Botanists and plant collectors have according to (Wood & Lenne, 2001) repeatedly and emphatically noted the existence of dense stands of wild relatives of wheat. For example, in the Near East, (Harlan, 1992) noted that ‘massive stands of wild wheats cover many square kilometers. (Hillmann, 1996) reported that 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 wheats under traditional management. (Harlan & Zohary, 1966) noted that wild Einkorn ‘occurs in massive stands as high as 2000 meters [altitude] in south-eastern Turkey and Iran’. 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). According to (Wood & Lenne, 2001) they are the strongest examples embracing wild progenitors of wheat: (Anderson, 1998) recorded wild wheat growing in Turkey and Syria in natural, rather pure stands with a density of 300/ m^2.

Nevertheless, 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 ecosystems close (or seemingly close) to nature. Biodiversity in agricultural settings can be considered to be important at country level in areas where the proportion of land allocated to agriculture is high: Ammann in (Wolfenbarger et al., 2004). This is the case in continental Europe for example, where forty five percent of the land is dedicated to arable and permanent crops or permanent pasture. In the UK, this figure is even higher, at seventy percent. Consequently, biodiversity has been heavily influenced by humans for centuries, and changes in agrobiological 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 & 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 et al., 2000).

Centers of biodiversity are a controversial matter, and even the definition of centers of crop biodiversity is still debated. Harlan (Harlan, 1971) 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 noncenter in Africa; another center includes a north Chinese center and a noncenter in southeast Asia and the south Pacific, with the third system including a Central American center and a South American noncenter. He suggests that the centers and the noncenters interacted with each other.

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 et al., 1994; Tilman et al., 2005; Whitham et al., 1999). 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 & 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.

Loss of biodiversity

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 & Sutherland, 2002) for the postwar 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 biodiverse regions are also those of greatest poverty, highest population growth and greatest dependence upon local natural resources. (Lee & Jetz, 2008)

Introduced species, another 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 & Sukopp, 1993). Many of those survive and can, after years and even many decades of adaptation, begin to be invasive. This might be misconstrued as increasing biodiversity, but the final effect is sometimes the opposite. The introduced species often displace native species such that many native species become extinct or severely limited.

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 & 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.

Biodiversity should still act as biological insurance for ecosystem processes, except when mean trophic interaction strength increases strongly with diversity (Thebault & 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 (Davis, 2003) . Taken together, theory and data suggest that compared to intertrophic 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, metacommunity and even most community levels.

Two case studies on the impact of transgenic crops on biodiversity

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 et al., 1994; Fawcett & 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 erosionby water" (Fawcett & 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 & Towery, 2002). Herbicide tolerant cotton has been rapidly adopted since its introduction in (Fawcett 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 gyphosate-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.botanischergarten.ch/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 introdution of transgenic crops. But a closer, more differenciated look reveals this to be an “urban legend”: (Carpenter & Gianessi, 2000).

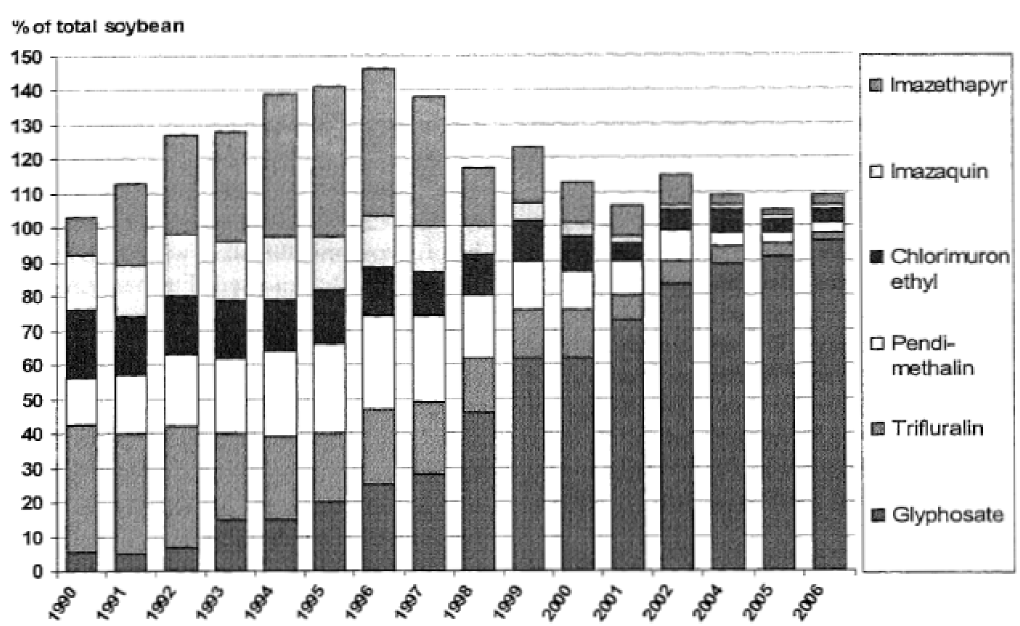

Fig. 1 1. Main herbicides used on total soybean acreage, 1990-2006 (as % of soybean surface treated by each herbicide) (From USDA NASS, 1991-2007). With the development of glyphosate-tolerant soybean, this herbicide is used far more extensively. Indeed, it replaces the herbicides used previously; the 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 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), Commelina benghalensis (trapoeraba), Spermacoce latifolia (erva-quente), *Richardia 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."

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 & Duke, 2006) with the same outcome as above.

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:

(Anderson, 2007; Bernoux et al., 2006; Beyer et al., 2006; Bolliger et al., 2006; Causarano et al., 2006; Chauhan et al., 2006; Etchevers et al., 2006; Gulvik, 2007; Knapen et al., 2007; Knowler & Bradshaw, 2007; Peigne et al., 2007; Raper & Bergtold, 2007; Thomas et al., 2007; Thompson et al., 2008; Wang et al., 2006).

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 on 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 et al., 2008; Duan et al., 2008; Marvier et al., 2007; Wolfenbarger et al., 2008)

(Wolfenbarger 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 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 incuded 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 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 wole, database robustnes 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. grandii* 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."

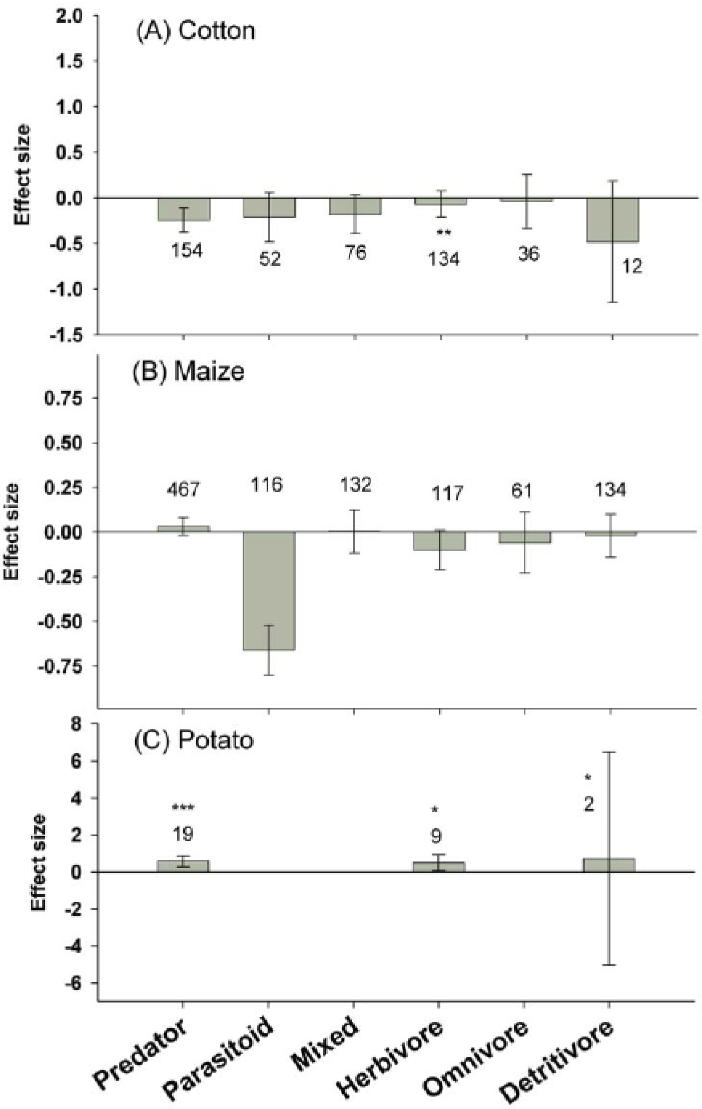

Fig. 2 The effect of Bt crops on non-target functional guilds compared to unsprayed, non-Bt control fields. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the comparisons (* ,0.05, ** ,0.01, * ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g001. Fig. 1 from (Wolfenbarger et al., 2008)**

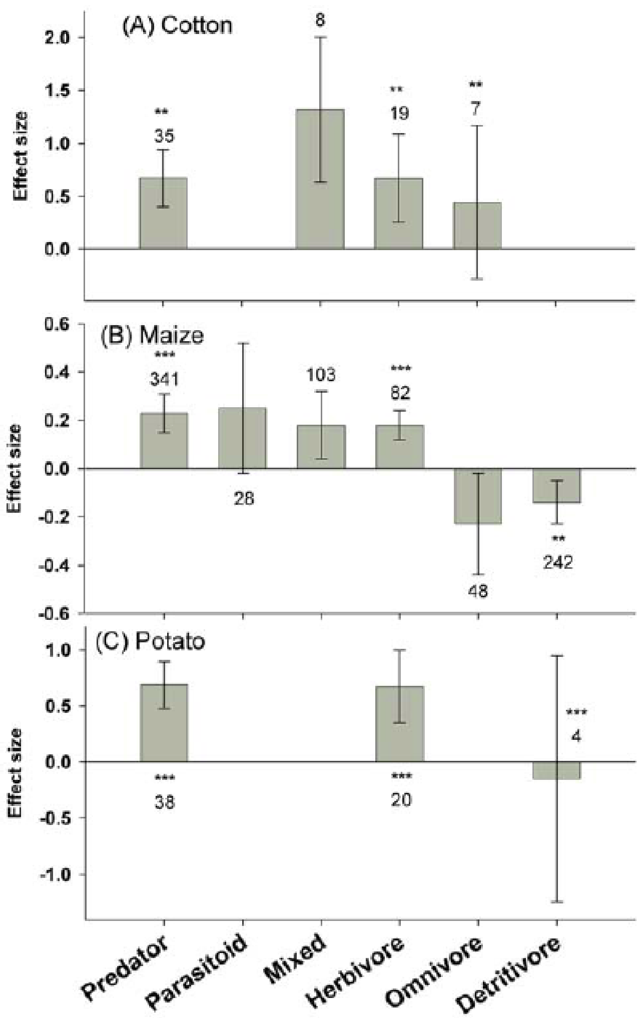

Fig. 3 The effect of Bt crops on non-target functional guilds compared to insecticide-treated, non-Bt control fields. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the studies (*,0.05, ** ,0.01, * ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g002. Fig. 2 from (Wolfenbarger 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."

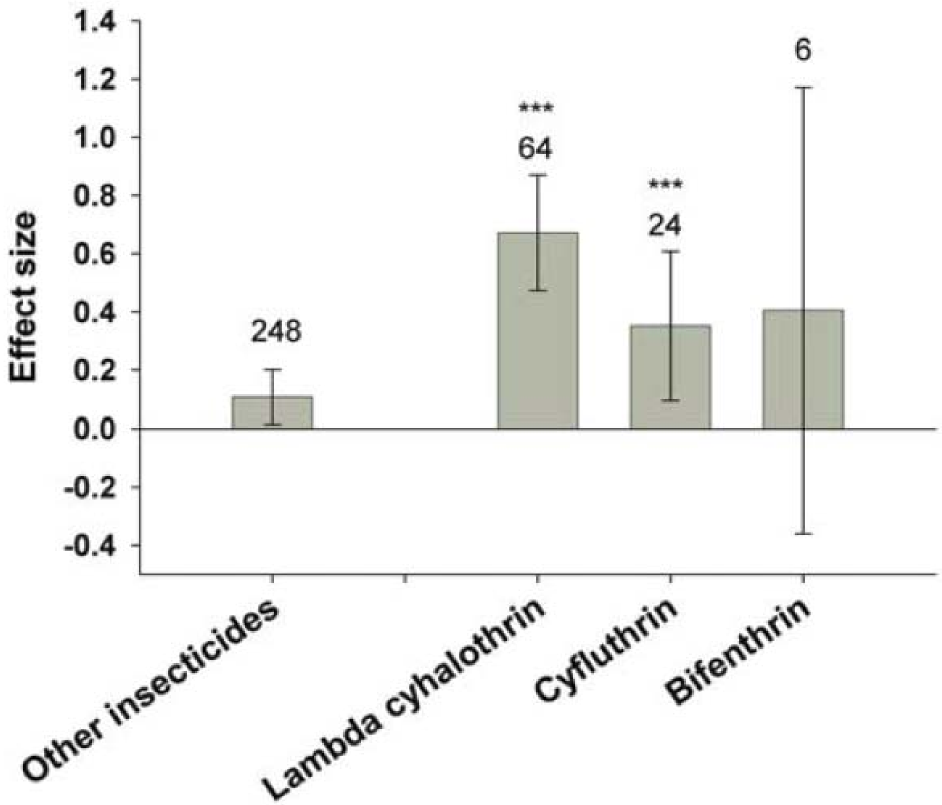

Fig. 4 Effects of Bt maize vs. control fields treated with a pyrethroid insecticide on predatory arthropods. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the studies (* ,0.05, ** ,0.01, * ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g003 . Fig. 3 from (Wolfenbarger 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.”

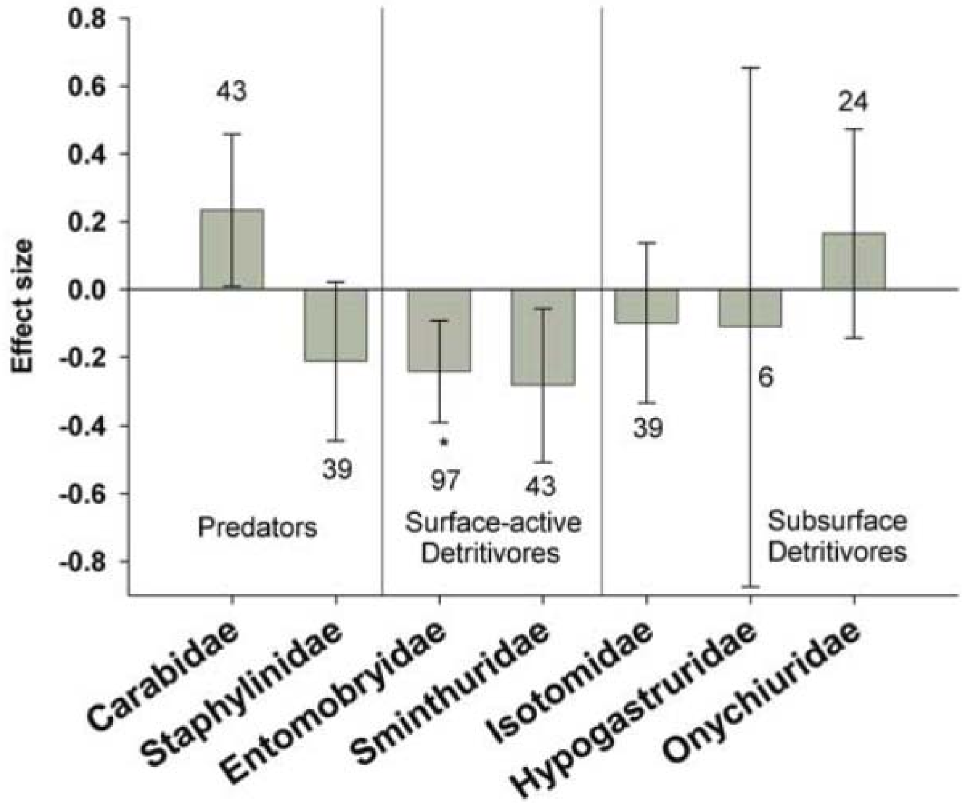

Fig. 5 Effect of Bt crops vs. insecticide-treated, non-Bt control fields on soil-inhabiting predators and detritivores. Bars denote the 95% confidence intervals, asterisks denote significant heterogeneity in the observed effect sizes among the studies (* ,0.05, ** ,0.01, * ,0.001), and Arabic numbers indicate the number of observations included for each functional group. doi:10.1371/journal.pone.0002118.g004. Fig. 4 from (Wolfenbarger et al., 2008)**

"The ''mixed'' functional group was more abundant in Bt maize (E = 0.1860.14, n= 103) compared with non-Bt maize treated with insecticides. The majority of this functional group is comprised of carabids (n= 33), nitidulids (n= 26), and mites (n =23).

For potatoes, the abundance of predators (E = 0.6960.30, n =38), but not herbivores, was significantly higher in the Bt crop (Fig 2c). Responses within each functional group were variable but sample sizes were too low to further partition this significant heterogeneity.

Predator-non target herbivore ratio analyses.

No significant change in predator-prey ratios was detected in cotton or potato; in maize there was a significantly higher predator- prey ratio in Bt maize plots than in the insecticide controls (E = 0.6360.42, n= 15). Significant heterogeneity for the predator: prey response existed in all three crops, but again sample sizes were too small to explore the cause of this variability.

Predator-detritivore analyses.

The higher abundance of detritivores in sprayed non-Bt maize appeared to be driven primarily by two families of Collembola with a high proportion of surface-active species (Entomobryidae: E=20.2460.15, n= 97;

Sminthuridae: E=20.2860.23, n= 43, Fig. 4). Three other families, Isotomidae, Hypogastruridae, and Onychiuridae, with more sub-surface species, were similar in Bt and non-Bt fields. We would expect surface-active collembolans to be more vulnerable to surface-active predators, and we detected a significantly lower abundance in one predator of Collembola (Carabidae: E= 0.2360.22, n= 43) but not in another (Staphylinidae: E=20.2160.23, n = 39, Fig 4). The other two detritivore families occupy different niches than Collembola and responded differently to insecticide treatments. The abundance of Japygidae (Diplura) was unchanged (E =20.1160.35, n= 9), but that for Lathridiidae (Coleoptera) was higher in Bt maize (E =0.7660.70, n =6), suggesting a direct negative effect of insecticides on this latter group. Lathridiid beetles, although being surface-active humusfeeders, are larger and more motile than Collembola and thus may be less vulnerable to predators and more vulnerable to insecticides."

As a whole, the study of Wolfenbarger et al. et al. did not reveal any negative effects, confirming for a large amount of data and publications the environmental benefits of the Bt maize tested.

American Soybean Association (2001)
Electronic Source: Homepage, published by: ASA
http://www.asa-europe.org/index.shtml

Anderson, P.C. (1998)
History of harvesting and threshing techniques for cereals in the prehistoric Near East. *In The Origins of Agriculture and Crop Domestication* (eds A.B. Damania, J. Valkoun, G. Willcox & C.O. Qualset), pp. 145-159. ICARDA, Aleppo

Anderson, R.L. (2007)
Managing weeds with a dualistic approach of prevention and control. A review. Agronomy for Sustainable Development, 27, 1, pp 13-18
<Go to ISI>://WOS:000245743500002

Attaran, A. & Maharaj, R. (2000)
Ethical debate - Doctoring malaria, badly: the global campaign to ban DDT. British Medical Journal, 321, 7273, pp 1403-1403
<Go to ISI>://WOS:000165720100035 AND http://www.botanischergarten.ch/DDT/Attaran-Doctoring-Badly-2000.pdf

Attaran, A., Roberts, D.R., Curtis, C.F., & Kilama, W.L. (2000)
Balancing risks on the backs of the poor. Nature Medicine, 6, 7, pp 729-+
<Go to ISI>://000088040100019 AND http://www.botanischergarten.ch/DDT/Attaran-Balancing-Poor-2000.pdf

Batista, R., Saibo, N., Lourenco, T., & Oliveira, M.M. (2008)
Microarray analyses reveal that plant mutagenesis may induce more transcriptomic changes than transgene insertion. Proceedings of the National Academy of Sciences of the United States of America, 105, 9, pp 3640-3645
<Go to ISI>://WOS:000253846500082 AND http://www.botanischergarten.ch/Genomics/Batista-Microarray-Analysis-2008.pdf

Baum, J.A., Bogaert, T., Clinton, W., Heck, G.R., Feldmann, P., Ilagan, O., Johnson, S., Plaetinck, G., Munyikwa, T., Pleau, M., Vaughn, T., & Roberts, J. (2007)
Control of coleopteran insect pests through RNA interference. Nature Biotechnology, 25, pp 1322-1326
<Go to ISI>://WOS:000251086500034 AND http://www.botanischergarten.ch/Genomics/Baum-RNA-interference-2007.pdf

Bellon, M.R. & Berthaud, J. (2004)
Transgenic maize and the evolution of landrace diversity in Mexico. The importance of farmers' behavior. Plant Physiology, 134, 3, pp 883-888
<Go to ISI>://000220360400001

Bellon, M.R. & Berthaud, J. (2006)
Traditional Mexican agricultural systems and the potential impacts of transgenic varieties on maize diversity. Agriculture and Human Values, 23, 1, pp 3-14
<Go to ISI>://000236273900002 AND http://www.botanischergarten.ch/Maize/Bellon-Impacts-Landraces-2006.pdf

Bellon, M.R., Berthaud, J., Smale, M., Aguirre, J.A., Taba, S., Aragon, F., Diaz, J., & Castro, H. (2003)
Participatory landrace selection for on-farm conservation: An example from the Central Valleys of Oaxaca, Mexico. Genetic Resources and Crop Evolution, 50, 4, pp 401-416

<Go to ISI>://000183201600008 AND http://www.botanischergarten.ch/Maize/Bellon-Participatory-Maize-2003.pdf

Benbrook, C. (2004)
Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years pp 53 pp Technical Paper Number 7 (Report)
http://www.botanischergarten.ch/HerbizideTol/Benbrook-First-nine-2004.pdf

Bernoux, M., Cerri, C.C., Cerri, C.E.P., Neto, M.S., Metay, A., Perrin, A.S., Scopel, E., Razafimbelo, T., Blavet, D., Piccolo, M.D., Pavei, M., & Milne, E. (2006)
Cropping systems, carbon sequestration and erosion in Brazil, a review. Agronomy for Sustainable Development, 26, 1, pp 1-8
<Go to ISI>://WOS:000236003300001

Berthaud, J. (2001)
Maize Diversity in Oaxaca, Mexico: Simple Questions but No Easy Answers, CIMMYT-Report pp 2 (Report)
http://www.cimmyt.cgiar.org/whatiscimmyt/AR002001Spa/latinamerica/maize/diversity.htm#Maize

Beyer, M., Klix, M.B., Klink, H., & Verreet, J.A. (2006)
Quantifying the effects of previous crop, tillage, cultivar and triazole fungicides on the deoxynivalenol content of wheat grain - a review. Journal of Plant Diseases and Protection, 113, 6, pp 241-246
<Go to ISI>://WOS:000243738300001

Bolliger, A., Magid, J., Amado, T.J.C., Neto, F.S., Ribeiro, M.D.D., Calegari, A., Ralisch, R., & de Neergaard, A. (2006)
Taking stock of the Brazilian "zero-till revolution": A review of landmark research and farmers' practice. Advances in Agronomy, Vol 91, 91, pp 47-110
<Go to ISI>://WOS:000244524100002

Bonny, S. (2008)
Genetically modified glyphosate-tolerant soybean in the USA: adoption factors, impacts and prospects. A review. Agronomy for Sustainable Development, 28, 1, pp 21-32
<Go to ISI>://WOS:000253779900003 AND http://www.botanischergarten.ch/Soya/Bonny-Soy-review-USA-2008.pdf

Carpenter, J. & Gianessi, L. (2000)
Herbicide use on roundup ready crops. Science, 287, 5454, pp 803-804
<Go to ISI>://000085136400019 AND http://www.botanischergarten.ch/HerbizideTol/CarpenterLetter-Herbicide-Use-2000.pdf

Cattivelli, L., Rizza, F., Badeck, F.W., Mazzucotelli, E., Mastrangelo, A.M., Francia, E., Mare, C., Tondelli, A., & Stanca, A.M. (2008)
Drought tolerance improvement in crop plants: An integrated view from breeding to genomics. Field Crops Research, 105, pp 1-14
<Go to ISI>://WOS:000252464800001 AND http://www.botanischergarten.ch/DroughtResistance/Cattivelli-Drought-Tolerance-2008.pdf

Causarano, H.J., Franzluebbers, A.J., Reeves, D.W., & Shaw, J.N. (2006)
Soil organic carbon sequestration in cotton production systems of the southeastern United States: A review. Journal of Environmental Quality, 35, 4, pp 1374-1383
<Go to ISI>://WOS:000239189900044

CBD (1992)
Electronic Source: Convention on Biological Diversity, published by: United Nations
http://www.biodiv.org/doc/publications/guide.asp

Cerdeira, A.L. & Duke, S.O. (2006)
The current status and environmental impacts of glyphosate-resistant crops: A review. Journal of Environmental Quality, 35, 5, pp 1633-1658
<Go to ISI>://000240924200001 AND http://www.botanischergarten.ch/HerbizideTol/Cerdeira-Status-2006.pdf

Cerdeira, A.L., Gazziero, D.L.P., Duke, S.O., Matallo, M.B., & Spadotto, C.A. (2007)

Review of potential environmental impacts of transgenic glyphosate-resistant soybean in Brazil. Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes, 42, 5, pp 539-549
<Go to ISI>://WOS:000247652600009 AND http://www.botanischergarten.ch/Soya/Cerdeira-Review-Potential-2007.pdf

Chauhan, B.S., Gill, G.S., & Preston, C. (2006)
Tillage system effects on weed ecology, herbicide activity and persistence: a review. Australian Journal of Experimental Agriculture, 46, 12, pp 1557-1570
<Go to ISI>://WOS:000241906000002

Chen, M., Zhao, J.-Z., Collins, H.L., Earle, E.D., Cao, J., & Shelton, A. (2008)
A Critical Assessment of the Effects of Bt Transgenic Plants on Parasitoids. PLoS ONE 3, 5, pp Published online 2008 May 28. doi: 10.1371 AND http://www.physorg.com/news131726113.html AND http://www.botanischergarten.ch/Bt/Chen-Critical-Assessment-2008.pdf AND http://www.botanischergarten.ch/Bt/Chen-Critical-TableS1-additional-2008.doc AND http://www.botanischergarten.ch/Bt/Chen-Critical-Figure-Dose-additional-2008.doc

Cotton Council (2003)
Electronic Source: National Cotton Council of America, published by: Cotton Council
http://www.cotton.org/

Curtis, C.F. (2002)
Restoration of malaria control in the Madagascar highlands by DDT spraying. American Journal of Tropical Medicine and Hygiene, 66, 1, pp 1-1
<Go to ISI>://000176672500001 AND http://www.botanischergarten.ch/DDT/Curtis-Restoration-DDT-2002.pdf

Curtis, C.F. & Lines, J.D. (2000)
Should DDT be banned by international treaty? Parasitology Today, 16, 3, pp 119-121
<Go to ISI>://000085712500012 AND http://www.botanischergarten.ch/DDT/Curtis-DDT-ban-2000.pdf

Darwin, C. (1845) Journal of Researches into the Natural History and Geology of the Countries Visited During the Voyage of H.M.S. Beagle Round the World,, nd ed. edn. John Murray, London, pp
http://darwin-online.org.uk

Davis, M.A. (2003)
Biotic globalization: Does competition from introduced species threaten biodiversity? Bioscience, 53, 5, pp 481-489
<Go to ISI>://000182833000011 AND http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit/Davis-Competition-2003.pdf

Dollaker, A. (2006)
Conserving biodiversity alongside agricultural profitability through integrated R&D approaches and responsible use of crop protection products. Pflanzenschutz-Nachrichten Bayer, 59, 1, pp 117-134

Dollaker, A. & Rhodes, C. (2007)
Integrating crop productivity and biodiversity conservation pilot initiatives developed by Bayer CropScience, in Weed Science in Time of Transition. Crop Science, 26, 3, pp 408-416
http://www.sciencedirect.com/science/article/B6T5T-4MV1NS0-1/2/45ef7df1e5582e65fbde44fa32651b26

Duan, J.J., Marvier, M., Huesing, J., Dively, G., & Huang, Z.Y. (2008)
A Meta-Analysis of Effects of Bt Crops on Honey Bees (Hymenoptera: Apidae). PLoS ONE, 3, 1, pp e1415
http://dx.doi.org/10.1371%2Fjournal.pone.0001415 AND http://www.botanischergarten.ch/Bt/Duan-Meta-Analysis-Effects-Bees-2008.pdf

Etchevers, J.D., Prat, C., Balbontin, C., Bravo, M., & Martinez, M. (2006)
Influence of land use on carbon sequestration and erosion in Mexico, a review. Agronomy for Sustainable Development, 26, 1, pp 21-28
<Go to ISI>://WOS:000236003300003

Evans, L.T. (1998) Feeding the Ten Billion: Plants and Population Growth, Cambridge University Press, Cambridge, UK., pp p. 34

Fawcett, R., Christensen, B., & Tierney, D. (1994)
The impact of conservation tillage on pesticide runoff into surface water., 49, pp 126-135
http://www.scientific-alliance.org/scientist_writes_items/benefits_no_till.htm

Fawcett, R. & Towery, D. (2002)
Electronic Source: Conservation tillage and plant biotechnology: How new technologies can improve the environment by reducing the need to plow., published by: Purdue University
www.ctic.purdue.edu/CTIC/CTIC.html or http://www.botanischergarten.ch/HerbizideTol/Fawcett-BiotechPaper.pdf

Fedoroff, N.V. & Cohen, J.E. (1999)
Plants and population: Is there time? Proceedings of the National Academy of Sciences of the United States of America, 96, 11, pp 5903-5907
<Go to ISI>://000080527100005 AND http://www.botanischergarten.ch/biodiversity/Fedorova-Time-1999.pdf

Gagnon, P.R. & Platt, W.J. (2008)
Multiple disturbances accelerate clonal growth in a potentially monodominant bamboo. Ecology, 89, 3, pp 612-618
<Go to ISI>://WOS:000254678200003

Gould, F. (2000)
Testing Bt refuge strategies in the field. Nature Biotechnology, 18, 3, pp 266-267
<Go to ISI>://000085771100017

Gulvik, M.E. (2007)
Mites (Acari) as indicators of soil biodiversity and land use monitoring: A review. Polish Journal of Ecology, 55, pp 415-440
<Go to ISI>://WOS:000249478600001

Harlan, J. & Zohary, D. (1966)
Distribution of wild wheats and barley. Science, 153, pp 1074-1080

Harlan, J.R. (1971)
Agricultural Origins - Centers and Noncenters. Science, 174, 4008, pp 468-&
<Go to ISI>://A1971K638500005 and http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit/Harlan-Centers-1971.pdf

Harlan, J.R. (1989)
Wild-grass harvesting in the Sahara and Sub-Sahara of Africa. *In Foraging and Farming: the Evolution of Plant Exploitation* (eds D.R. Harris & G.C. Hillman), pp. 79–98, 88–91 and Figures. 5.2–5.3. Unwin Hyman, London
Harlan, J.R. (1992) Crops and Man, 2nd edition American Society of Agronomy, Madison, Wisconsin, IS: 0-89118-107-5, pp 295

Henneman, M.L. & Memmott, J. (2001)
Infiltration of a Hawaiian Community by Introduced Biological Control Agents. Science, 293, 5533, pp 1314-1316
http://www.sciencemag.org/cgi/content/abstract/293/5533/1314 and
http://www.botanischergarten.ch/BioControl/Hennemann-Science-2001.pdf

Hillmann, G. (1996)
'Late Pleistocene changes in wild food plants available to huntergatherers of the northern Fertile Crescent:possible preludes to cereal cultivation. *In The Origin and Spread of Agriculture and Pastoralism in Eurasia,* (ed D.R. Harris), pp. 159–203, p 189. University College Press, London
Horton, J.E. (2000)
Caution required with the precautionary principle. The Lancet, 356, 9226, pp 265-265
http://www.sciencedirect.com/science/article/B6T1B-40W5V2N-1/1/8f70aae7435c15851abc3ee30f8d0572
AND http://www.botanischergarten.ch/DDT/Horton-Caution-with-Precautionary-Principle-2000.pdf

Howarth, F.G. (1991)
Environmental Impacts of Classical Biological-Control. Annual Review of Entomology, 36, pp 485-509
<Go to ISI>://A1991EQ80700021

Janzen, D. (1998)

Gardenification of wildland nature and the human footprint. Science, 279, 5355, pp 1312-1313
<Go to ISI>://000072251800035 AND http://www.botanischergarten.ch/biodiversity/Janzen-Gardenification-SM-1998.pdf

Janzen, D. (1999)
Gardenification of tropical conserved wildlands: Multitasking, multicropping, and multiusers. Proceedings of the National Academy of Sciences of the United States of America, 96, 11, pp 5987-5994
<Go to ISI>://000080527100018 AND http://www.botanischergarten.ch/biodiversity/Janzen-Gardenification-1999.pdf

Kier, G., Mutke, J., Dinerstein, E., Ricketts, T.H., Kuper, W., Kreft, H., & Barthlott, W. (2005)
Global patterns of plant diversity and floristic knowledge. Journal of Biogeography, 32, 7, pp 1107-1116
<Go to ISI>://00022970590000

Knapen, A., Poesen, J., Govers, G., Gyssels, G., & Nachtergaele, J. (2007)
Resistance of soils to concentrated flow erosion: A review. Earth-Science Reviews, 80, 1-2, pp 75-109
<Go to ISI>://WOS:000243646800003

Knowler, D. & Bradshaw, B. (2007)
Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy, 32, 1, pp 25-48
<Go to ISI>://WOS:000243569800002

Kowarik, I. (2005)
Urban ornamentals escaped from cultivation. *In Crop Ferality and Volunteerism* (ed J. Gressel). CRC Press, Boca Raton

Kuper, W., Sommer, J.H., Lovett, J.C., Mutke, J., Linder, H.P., Beentje, H.J., Van Rompaey, R., Chatelain, C., Sosef, M., & Barthlott, W. (2004)
Africa's hotspots of biodiversity redefined. Annals of the Missouri Botanical Garden, 91, 4, pp 525-535
<Go to ISI>://000226362700001 AND http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit/Kueper-Hotspots-2004.pdf

Lee, T.M. & Jetz, W. (2008)
Future battlegrounds for conservation under global change. Proceedings of the Royal Society B-Biological Sciences, 275, 1640, pp 1261-1270
<Go to ISI>://WOS:000255056600005 AND http://www.botanischergarten.ch/BiodiversityAgri/Lee-Future-Battlegrounds-2008.pdf

Lughadha, E.N., Baillie, J., Barthlott, W., Brummitt, N.A., Cheek, M.R., Farjon, A., Govaerts, R., Hardwick, K.A., Hilton-Taylor, C., Meagher, T.R., Moat, J., Mutke, J., Paton, A.J., Pleasants, L.J., Savolainen, V., Schatz, G.E., Smith, P., Turner, I., Wyse-Jackson, P., & Crane, P.R. (2005)
Measuring the fate of plant diversity: towards a foundation for future monitoring and opportunities for urgent action. Philosophical Transactions of the Royal Society B-Biological Sciences, 360, 1454, pp 359-372
<Go to ISI>://000228214600011

Mallory, A.C. & Vaucheret, H. (2006)
Functions of microRNAs and related small RNAs in plants. Nature Genetics, 38, pp S31-S36
<Go to ISI>://000202983200007 AND http://www.botanischergarten.ch/Genomics/Mallory-MicroRNAs-2006.pdf

Marvier, M., McCreedy, C., Regetz, J., & Kareiva, P. (2007)
A Meta-Analysis of Effects of Bt Cotton and Maize on Nontarget Invertebrates. Science %R 10.1126/science.1139208, 316, 5830, pp 1475-1477
http://www.sciencemag.org/cgi/content/abstract/316/5830/1475 AND http://www.botanischergarten.ch/Bt/Marvier-Meta-Analysis-2007.pdf AND supporting data: http://www.botanischergarten.ch/Bt/Marvier-Meta-Analysis-Supporting-2007.pdf

Mattick, J.S. (2004)
The hidden genetic program of complex organisms. Scientific American, 291, 4, pp 60-67
<Go to ISI>://WOS:000223903500025 AND http://www.botanischergarten.ch/Genomics/Mattick-Genome-Complexity-2004.pdf

May, R.M. (1990)

How Many Species. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 330, 1257, pp 293-304
<Go to ISI>://WOS:A1990EM43100015 AND http://www.botanischergarten.ch/BiodiversityAgri/May-How-many-Species-1990.pdf

Morris, W.F., Kareiva, P.M., & Raymer, P.L. (1994)
Do Barren Zones and Pollen Traps Reduce Gene Escape from Transgenic Crops. Ecological Applications, 4, 1, pp 157-165
<Go to ISI>://A1994MU60500017 AND http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit-1/Morris-Barrenzones-1994.pdf

Mucher, C.A., Steinnocher, K.T., Kressler, F.P., & Heunks, C. (2000)
Land cover characterization and change detection for environmental monitoring of pan-Europe International Journal of Remote Sensing,, 21, 6-7, pp 1159-1181
http://www.ingentaconnect.com/content/tandf/tres/2000/00000021/F0020006/art00006
http://dx.doi.org/10.1080/014311600210128 AND http://www.botanischergarten.ch/BiodiversityAgri/Mucher-Land-Cover-2000.pdf

Nevo, E. (1998)
Genetic diversity in wild cereals: Regional and local studies and their bearing on conservation ex situ and in situ. Genetic Resources and Crop Evolution, 45, 4, pp 355-370
<Go to ISI>://000075583700010

Peigne, J., Ball, B.C., Roger-Estrade, J., & David, C. (2007)
Is conservation tillage suitable for organic farming? A review. Soil Use and Management, 23, 2, pp 129-144
<Go to ISI>://WOS:000247401500003

Prain, D. (1903) 'Flora of the Sundribuns, pp 231–370, p 357.

Purvis, A. & Hector, A. (2000)
Getting the measure of biodiversity. Nature, 405, 6783, pp 212-219
http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v405/n6783/full/405212a0_fs.html

Raikhel, N.V. & Minorsky, P.V. (2001)
Celebrating Plant Diversity. Plant Physiol. %R 10.1104/pp.900012, 127, 4, pp 1325-1327
http://www.plantphysiol.org AND http://www.botanischergarten.ch/Genomics/Raikhel-Celebrating-Plant-Diversity-2001.pdf

Raper, R.L. & Bergtold, J.S. (2007)
In-row subsoiling: A review and suggestions for reducing cost of this conservation tillage operation. Applied Engineering in Agriculture, 23, 4, pp 463-471
<Go to ISI>://WOS:000248928500009

Roberts, D.R., Manguin, S., & Mouchet, J. (2000)
DDT house spraying and re-emerging malaria. The Lancet, 356, 9226, pp 330-332
http://www.sciencedirect.com/science/article/B6T1B-40W5V2N-S/1/45b7aced36db0dc7f42edeb587257897 AND http://www.botanischergarten.ch/DDT/Roberts-DDT-House-spraying-2000.pdf

Robinson, R.A. & Sutherland, W.J. (2002)
Post-war changes in arable farming and biodiversity in Great Britain. Journal of Applied Ecology, 39, 1, pp 157-176
http://www.botanischergarten.ch/Bt/Robinson-Post-war-Changes-Biodiversity-2002.pdf

Schlapfer, F., Pfisterer, A.B., & Schmid, B. (2005)
Non-random species extinction and plant production: implications for ecosystem functioning. Journal of Applied Ecology, 42, 1, pp 13-24
<Go to ISI>://000227175200003

Schofield, P.J. & Chapman, L.J. (1999)
Interactions between Nile perch, Lates niloticus, and other fishes in Lake Nabugabo, Uganda. Environmental Biology of Fishes, 55, 4, pp 343-358
<Go to ISI>://WOS:000082086100001

Smith, A.G. (2000)

How toxic is DDT? The Lancet, 356, 9226, pp 267-268
http://www.sciencedirect.com/science/article/B6T1B-40W5V2N-3/1/478cd64886d364af58f6b73351114698
AND http://www.botanischergarten.ch/DDT/Smith-How-toxic-DDT-2000.pdf

Sukopp, H. & Sukopp, U. (1993)
Ecological Long-Term Effects of Cultigens Becoming Feral and of Naturalization of Nonnative Species. Experientia, 49, 3, pp 210-218

Taverne, J. (1999)
DDT - to Ban or not to Ban? Parasitology Today, 15, 5, pp 180-181
http://www.sciencedirect.com/science/article/B6TB8-3WRB3N6-1K/1/01c87ce34b7286d71b07a1f2bc49c982
AND http://www.botanischergarten.ch/DDT/Taverne-toban-nottoban-1999.pdf

Thebault, E. & Loreau, M. (2005)
Trophic interactions and the relationship between species diversity and ecosystem stability. American Naturalist, 166, 4, pp E95-E114
<Go to ISI>://000232270600002

Thomas, G.A., Titmarsh, G.W., Freebairn, D.M., & Radford, B.J. (2007)
No-tillage and conservation farming practices in grain growing areas of Queensland - a review of 40 years of development. Australian Journal of Experimental Agriculture, 47, 8, pp 887-898
<Go to ISI>://WOS:000248021900001

Thompson, J.P., Owen, K.J., Stirling, G.R., & Bell, M.J. (2008)
Root-lesion nematodes (Pratylenchus thornei and P. neglectus): a review of recent progress in managing a significant pest of grain crops in northern Australia. Australasian Plant Pathology, 37, 3, pp 235-242
<Go to ISI>://WOS:000254549200004

Tilman, D. (2000)
Causes, consequences and ethics of biodiversity. Nature, 405, 6783, pp 208-211
3-Biodiv-Nature-Insight-Causes-Tilman.pdf

Tilman, D., Polasky, S., & Lehman, C. (2005)
Diversity, productivity and temporal stability in the economies of humans and nature. Journal of Environmental Economics and Management, 49, 3, pp 405-426
<Go to ISI>://000229345100001 AND http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit/Tilman-Diversity-Stability-2005.pdf

Tren, R. & Bate, R. (2001) Malaria and the DDT Story iea, The Institute of Economic Affairs, London, IS: 0 255 36499 7, pp 112
http://www.botanischergarten.ch/DDT/Tren-Bate-IEA-DDT-story-2001.pdf

Trewavas, A.J. (2001)
The population/biodiversity paradox. Agricultural efficiency to save wilderness. Plant Physiology, 125, 1, pp 174-179
http://www.plantphysiol.org/cgi/reprint/125/1/174.pdf

Trewawas, A. (2003)
Electronic Source: Benefits To The Use Of Gm Herbicide Tolerant Crops- The Challenge Of No-Till Agriculture, published by: Scientific Alliance
http://www.scientific-alliance.org/scientist_writes_items/benefits_no_till.htm

Vareschi, V. (1980) Vegetationsökologie der Tropen Ulmer, Stuttgart, IS: 3800134233, pp 294
see also http://www.payer.de/cifor/cif0203.htm

Wang, X.B., Cai, D.X., Hoogmoed, W.B., Oenema, O., & Perdok, U.D. (2006)
Potential effect of conservation tillage on sustainable land use: A review of global long-term studies. Pedosphere, 16, 5, pp 587-595
<Go to ISI>://WOS:000240820200006

Whitham, T.G., Martinsen, G.D., Floate, K.D., Dungey, H.S., Potts, B.M., & Keim, P. (1999)
Plant hybrid zones affect biodiversity: Tools for a genetic-based understanding of community structure. Ecology, 80, 2, pp 416-428

<Go to ISI>://000079036500007 AND http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit-1/Witham-biodiversiy-hybrids-1999.pdf

WHO (2005)
WHO Position On DDT Use In Disease Vector Control Under The Stockholm Convention On Persistent Organic Pollutants, WHO pp 2 Geneva (Report)
http://www.botanischergarten.ch/DDT/WHO-Position-on-DDT-2005.pdf

Witcombe, J.R., Hollington, P.A., Howarth, C.J., Reader, S., & Steele, K.A. (2008)
Breeding for abiotic stresses for sustainable agriculture. Philosophical Transactions of the Royal Society B-Biological Sciences, 363, pp 703-716
<Go to ISI>://WOS:000252663200003 AND http://www.botanischergarten.ch/DroughtResistance/Witcombe-Breeding-abiotic-Stress-2008.pdf

Wolfenbarger, L.L., Andow, D.A., Hilbeck, A., Nickson, T., Wu, F., Thompson, P.B., & Ammann, K. (2004)
GE crops: balancing predictions of promise and peril. Frontiers in Ecology and the Environment, 2, 3, pp 154-160
<Go to ISI>://000223960400019 AND www.frontiersinecology.org and http://www.botanischergarten.ch/Frontiers-Ecology/Ammann-Forum-def1.pdf

Wolfenbarger, L.L., Naranjo, S.E., Lundgren, J.G., Bitzer, R.J., & Watrud, L.S. (2008)
Bt Crop Effects on Functional Guilds of Non-Target Arthropods: A Meta-Analysis. PLoS ONE, 3, 5, pp e2118
http://dx.doi.org/10.1371%2Fjournal.pone.0002118 AND http://www.botanischergarten.ch/Bt/LaReesa-Bt-crop-Meta-Analysis-2008.pdf AND http://www.botanischergarten.ch/Bt/LaReesa-Meta-Analysis-Powerpoints-2008.ppt

Wood, D. & Lenne, J. (1999)
Agrobiodiversity and Natural Biodiversity: Some Parallels. *In Agrobiodiversity, Characterization, Utilization and Management* (eds D. Wood & J. Lenne), pp. 425-445. CABI, Oxon, UK and New York, N.Y. USA

Wood, D. & Lenne, J. (2001)
Nature's fields: a neglected model for increasing food production. Outlook on Agriculture, 30, 3, pp 161-170
<Go to ISI>://000171396200003 AND http://www.botanischergarten.ch/Organic/Wood-Natures-Fields-2001.pdf

World Resources Institute (2000)
People and Ecosystems, The Frayling Web of Life, World Resources Institute, UNDP, UNEP, World Bank, pp 36 Washington (Report)
http://www.wri.org/wr2000/pdf/summary.pdf