

How to deal with traditional knowledge in modern agriculture

A User's Guide for Building Bridges

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KLAUS AMMANN, Guest Professor, TU Delft, Netherlands, klaus.ammann@ips.unibe.ch

Abstract

This contribution seeks to analyze the seemingly big contrast between traditional and scientific knowledge, and between traditional agriculture (focus: organic farming) and biotechnology-based farming (focus: transgenic crops first generation). It will be shown, that the contrasts are not as big as often claimed and the consequences are that organic farming and biotechnology-based strategies could go easily together, but only if conceptual contrasts are overcome, despite of strong prejudice from both sides.

1. Preface, the international scene in the protection of biodiversity

Since the adoption of the Convention on Biodiversity in 1992 (CBD, 1992), the law of plant genetic resources and the legal status of traditional knowledge was paid increasing attention in international fora, non-governmental organizations and academic research. The steady loss of biodiversity in plant genetic resources (CBD-SBSTTA, 1999), the contrast between protected plant varieties and genetically engineered products on the one hand, and traditional crops and landraces in the public domain on the other hand, the advent of the TRIPs Agreement within the World Trade Organization in 1995 and the International Treaty on Plant Genetic Resources for Agriculture, all stimulated an increasing debate (Giannakas, 2003). The Doha Agenda Ministerial Declaration (WTO Doha Ministerial Declaration, 2001) explicitly endorsed the issue of traditional knowledge as subject for further work. It should influence the future of the global IPR and trading system, and will be influenced by it. What, some years ago, was a concern limited to ecological aspects of preserving biodiversity, has moved centre stage and affects the legitimacy of the multilateral trading system, intellectual property in particular and its interface with modern agricultural and environmental policies.

A major problem of this system is the relationship between varying negotiation processes in different fora. Another closely connected problem is the contradictory relationship between different regulatory levels at different spatial scales (international, regional, local) (Brand & Gorg, 2003). It will be of prime importance to move towards a reconciliation between the CBD and the TRIPS agreement (Curci Staffler, 2003). However, we must see the full complexity of the issues related to biodiversity (Biber Klemm & Cottier, 2006; Girsberger, 1999). It will not at all be easy to overcome the difficulties: One should insist to have a close look on how power structures knowledge, otherwise attempts to work in the interests of indigenous people will fail. This will also necessitate to lobby governments, to question unwise application of science and some views of ecologists, to strengthen independent decision-making processes among indigenous people and scientists. To productively engage indigenous knowledge in development, we must go beyond the dichotomy of indigenous vs. scientific knowledge, challenge both, and work towards greater autonomy in participatory projects and produce new visions for scientific regulation (Miller, 2007). The Cartagena Biosafety Protocol is today seen by many scientists as going too far in regulation, completely focusing on the methodology of modern breeding of transgenic plants, taking into account exclusively the risks. It has unfortunately evolved into a major obstacle for agricultural innovation. Agricultural innovation has always been knowledge based, foremost relying on farmers experience. With the development of modern science applied also to agriculture, the scene has been changed considerably. Without any doubt modern agriculture has taken advantage of the emerging molecular biology and rapidly growing knowledge in scientific ecology. In the past years this has been paired with unwise disregard of traditional knowledge in agriculture (by the side: also in the developed world!)

It will be of prime importance to move towards a reconciliation between the CBD and the TRIPS agreement. However, we must see the full complexity of the issues. It will not at all be easy to overcome the difficulties: In enunciating a critique of the utopian nature of particular attempts to strengthen the position of indigenous peoples vis-à-vis others, one should insist to have a look at the basic question on *how power is structuring knowledge and vice versa*, otherwise attempts to work in the interests of indigenous people will fail. This will also necessitate to lobby governments, question science, strengthen independent decision making processes among indigenous people – it will not be enough to document traditional knowledge alone. To productively engage indigenous knowledge in development, we must go beyond the dichotomy of indigenous vs. scientific knowledge, and work towards a better integration of traditional and scientific knowledge.

It should also be made clear that future regulation on IP will have to include humanitarian aspects and a need to comply to the special needs of smallholder agriculture: As has been made clear by industry and leading universities in the field of biotechnology, it will be necessary to introduce new rules, they have to comply with the extremely low cash flow of smallholders in the developing world, who cannot afford to pay royalties for GM seeds (Atkinson, 2003; Atkinson et al., 2003; Beachy, 2003).

It will be necessary to overcome the compartmentalized view of Western science, and try to again integrate traditional knowledge. The Rio Convention is a remarkable framework document focusing not merely on conservation but also on the sustainable use of genetic resources and the fair sharing of the benefits arising from them. In particular, the provisions concerning access and benefit-sharing and the protection of traditional knowledge emerged as a hot topic of recent debate that calls for innovative solutions. The same compartmentalization between Western Science and traditional knowledge has also caused the growing divide on views of agricultural management. Nowadays the concept of biodiversity has unfortunately often evolved into an unreflected mantra of many environmentalists, sometimes heading towards unthoughtful eco-imperialism. We should avoid seeking to force biodiversity perspectives in an unthoughtful way into our daily life, particularly agriculture. We all agree that agriculture needs to become more sustainable, and sustainability has a lot to do with biodiversity, but we should also be able to critically reflect on the role of biodiversity and put it into factual relationship with all elements of agriculture, namely the need for higher production in spite of the fact, that there would be since many years enough food around – but this is illusionary, since its not just a quantitative problem, there are unfortunately unsurmountable logistical and often also political obstacles encountered.

This contribution concentrates on the issue of traditional knowledge and agro-ecology in all variants, comparing it to recent scientific insights and the resulting modern agriculture, which is in its seemingly big contrast to traditional forms of agriculture one of the major problems to overcome. We need to realize that on the surface there are major cultural and philosophical differences in concepts of traditional and scientific knowledge, but in essence there are also striking similarities to observe. In order to overcome major misunderstandings and to create new and surprising outlooks, we advocate discursive systems of debate, which take into account different kinds of knowledge and acts along the lines of the 'Symmetry of Ignorance'. (Ammann & Papazova Ammann, 2004). This will lead in a long decision making process also to a reconciliation between organic and biotech based farming. This is not a new idea, it has already been avocated by (Swaminathan, 2001): By integrating pre-breeding in advanced laboratories with participatory breeding with farm families, the advantages of genetic efficiency and diversity can be combined. Even earlier (Ngoc Hai, 1998) states bluntly the need for biotechnology in organic farming for developing countries. See also (Ammann, 1999).

2. Definition of traditional knowledge

Observing the seemingly huge differences in tradition and structure of indigenous and western life – the contrasts are obvious and lead to misunderstandings that thinking of the human beings of such diverse societies must also be basically different. It is true, that religious traditions and rituals of indigenous people can be perceived in dramatic contrast to western life in all its modernity. And worse: western intellectuals tend to romanticize animistic views with all its still largely untapped richness, making the contrasts even greater, instead of searching for commonalities in human thinking in all cultures.

According to (Berkes et al., 2000), traditional knowledge is a way of knowing and is similar to Western science in that it is based on an accumulation of observations, but it is different from science in some fundamental ways. The anthropologist (Levi-Strauss, 1962) argued that these two ways of knowing are two parallel modes of acquiring knowledge about the universe; the two sciences were fundamentally distinct in that “the physical world is approached from opposite ends in the two cases: one is supremely concrete, the other supremely abstract.”

Similarly, the philosopher (Feyerabend, 1987) distinguished between two different traditions of thought: abstract traditions (to which scientific ecology belongs) and historical traditions, which include systems of knowledge possessed by people outside Western science, knowledge that often becomes encoded in rituals and in the cultural practices of everyday life.

Traditional knowledge may be holistic in outlook and adaptive by nature, gathered over generations by observers whose lives depended directly on this information and its use. It often accumulates incrementally, it is attested by trial-and-error and transmitted to future generations orally or by shared practical experiences (Ohmagari & Berkes, 1997).

Case studies revealed that there exists a diversity of local or traditional practices for ecosystem management (Berkes et al., 2007). These include multiple species management, resource rotation, succession management, landscape patchiness management, and other ways of responding to and managing pulses and ecological surprises. Social mechanisms behind these traditional practices include a number of adaptations for the generation, accumulation, and transmission of knowledge; the use of local institutions to provide leaders/stewards and rules for social regulation; mechanisms for cultural internalization of traditional practices; and the development of appropriate world views and cultural values. The use of the term “Traditional Ecological Knowledge” has become established, among others, through the work of the International Conservation Union (IUCN) working group by that name (Johannes, 1989; Williams & Baines, 1993). Traditional Ecological Knowledge and Wisdom (TEKW) has now become established as a major term in all fields of ecology, including agriculture (Turner & Berkes, 2006; Turner et al., 2003; Turner et al., 2000).

The components have been summarized in a figure in (Turner et al., 2000):

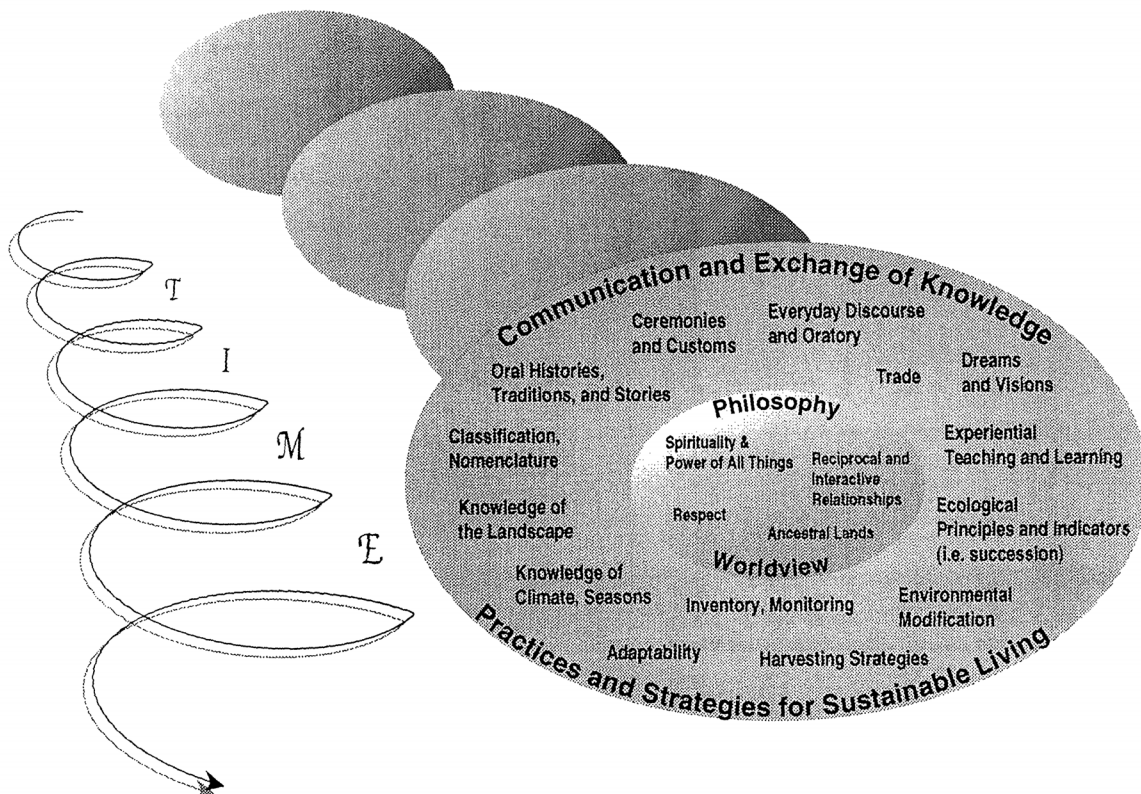


Fig. 1 Components of traditional ecological knowledge and wisdom of aboriginal peoples of northwestern North America. From (Turner et al., 2000).

3. Resolving the contrasts between traditional and scientific knowledge

(Agrawal, 1995; Agrawal, 1997) claim both that by distinguishing indigenous knowledge from scientific knowledge, theorists are caught in a dilemma. Focus on indigenous knowledge has gained native peoples an audible voice in development. Yet, this distinction creates a dichotomy between indigenous and scientific knowledge. This dichotomy is especially problematic because it often hinders exchange and communication between the two types of knowledge. But (Agrawal, 1995; Agrawal, 1997) argue that a basic distinction between indigenous and scientific is completely artificial. Keeping up this artificial barrier is also one of the reasons why there is such a seemingly insurmountable contrast between organic farming, subsistence farming and modern agriculture including biotechnology, as we will see in the following chapters. Most scientists depict traditional knowledge as unable to learn from experience, fuzzy in its concepts and closed to input from outside, whereas science is open to new thought, precise in its empirically tested progress and caring about the real needs of farmers. In contrast to this, indigenous farmers have often a mistrust against science being too abstract, analytical and divorced from the needs of the people. But the reality is different: Some analysis reveals that the differences are smaller: Traditional knowledge in ancient times was based on oral tradition which, over long periods of time, revealed to be strikingly precise and was making use of manifold empirically and by observation tested knowledge. In modern science, oral tradition is ironically enough still present (science communities with different views and language continue to exist regionally despite the internet, for instance in botanical nomenclature) and knowledge is verified or falsified by experiment and observation. (Feyerabend, 1987) notes critically, that scientists are often closed to matters outside science. However, as (Popper, 1972, 1994) rightly claims: The line must be drawn when a theory cannot be falsified, then it should not be called scientific. This concept actually also opens traditional knowledge to similar scrutinizing.

In the following chapters we shortly describe organic agriculture and biotechnology driven agriculture, leaving out for reason of simplicity all other agricultural and often intergrading strategies. And we know from the above lines, that the contrasts in knowledge should not be cultivated, both strategies considered here comprise traditional knowledge and empirical precision, the differences are based on emphasizing methodology, a view which we will challenge here.

There are many other authors emphasizing the commonalities between scientific and traditional knowledge, without making the mistake of putting them to synonymy: (Horton, 1967a, b) for instance cannot understand, that even those familiar with the theoretical thinking in their own Western tradition have failed to recognize its African equivalents, simply because they have been blinded by the differences in idiom, and that, consequently, an exhaustive exploration of features common to Western and traditional African thought should come before the enumeration of differences. This is certainly also true for any kind of traditional agricultural practices compared to Western science based agriculture.

4. Definition of present day organic farming

Organic farming (included in this comparison also some aspects of agro-ecological approaches in the sense of Altieri & Nicholls (Altieri & Nicholls, 2005)) has started as a heterogeneous management method in agriculture. This can be explained by its multiple origins, and by the fact that certification of organic farming practices with follow-up inspection has been introduced in various decades and many different places. Organic farming is now growing rapidly out of the corner of backward thinking luddites (although admittedly they are still there), becoming a veritable industry. Regulation has been imposed more or less strictly on all organic farms of states like California (Guthman, 1998). An international Federation of Organic Agriculture Movements (IFOAM) is now uniting the organic movements of the world with 750 members in 108 states, supported also by the United Nations FAO, www.ifoam.org. The website offers a lot of information, for instance some basic views on organic farming, such as the following four principles:

- Principle of health
Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- Principle of ecology
Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- Principle of fairness
Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities
- Principle of care
Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

The specific agricultural rules are still in an international debate in order to improve them, to find the right mix between regulatory strictness and allowing for a maximum diversity of the rules, some important documents like the draft principles exceed on purpose the basic principles of organic farming: (IFOAM, 2004a, b, c, 2007) in order to stimulate discussion and show targets and tendencies proposed.

Since 2005 (IFOAM, 2005) there is an official definition document existing on organic agriculture (the process is still going on and transparently elaborated at several positions of the IFOAM website). Here the latest example included into the document, without approving it definitely:

“Organic agriculture, as defined by IFOAM, includes all agricultural systems that promote environmentally, socially and economically sound production of food and fibers. Recycling nutrients and strengthening natural processes helps to maintain soil fertility and ensure successful production. By respecting the natural capacity of plants, animals and the landscape, it aims to optimize quality in all aspects of agriculture and the environment. Organic Agriculture dramatically reduces external inputs by refraining from the use of synthetic fertilizers and pesticides, Genetically Modified Organisms and pharmaceuticals. Pests and diseases are controlled with naturally occurring means and substances according to both traditional as well as modern scientific knowledge, increasing both agricultural yields and disease resistance. Organic agriculture adheres to globally accepted principles, which are implemented within local socio-economic, climatic and cultural settings. As a logical consequence, IFOAM stresses and supports the development of self-supporting systems on local and regional levels”. IFOAM Directory 2005 (most recent example)

This is a remarkable statement stressing exclusively the rural situation – but what about the rapidly growing urban areas. Also the statement ‘increasing both agricultural yields and resistance seem, in the light of a majority of scientific data, somehow euphemistic. (Slingerland: personal communication to which the author agrees).

Noteworthy is also, that even on the official IFOAM website and on several national websites on organic farming the debate on how to define organic agriculture still goes on.

The problem is, that top down regulation means to come to terms with standards met also in traditional agriculture such as defining levels of toxicity for biopesticides, which is often not easy (Guthman, 1998).

Altieri & Nicholls (Altieri & Nicholls, 2005) summarize their views of agro ecology, following Reijntjes et al. (Reijntjes et al., 1992) in: http://www.cnr.berkeley.edu/~agroeco3/principles_and_strategies.html

- Enhance recycling of biomass and optimizing nutrient availability and balancing nutrient flow.
- Securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.
- Minimizing losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover.
- Species and genetic diversification of the agro ecosystem in time and space.
- Enhance beneficial biological interactions and synergisms among agro biodiversity components thus resulting in the promotion of key ecological processes and services.

See publications of Altieri: (Altieri, 1981, 1992; Altieri et al., 1994, 2004; Altieri & Nicholls, 2005)

Note that Altieri and colleagues do not exclude explicitly transgenic plants, but on the other hand they are not holding back their opposition against multinational seed companies, whether justified or not, this is another matter – it might surprise some readers that in developing countries, there are only minimal conflicts between multinational seed companies and subsistence farming, if one follows official statistics published by Cohen (Cohen, 2005) and the FAO (Dhlamini et al., 2005).

Watson et al. elaborate on the principles of organic farming related to soil, giving an instructive summary scheme of the complex interrelationships in an agro-system: (Watson et al., 2002)

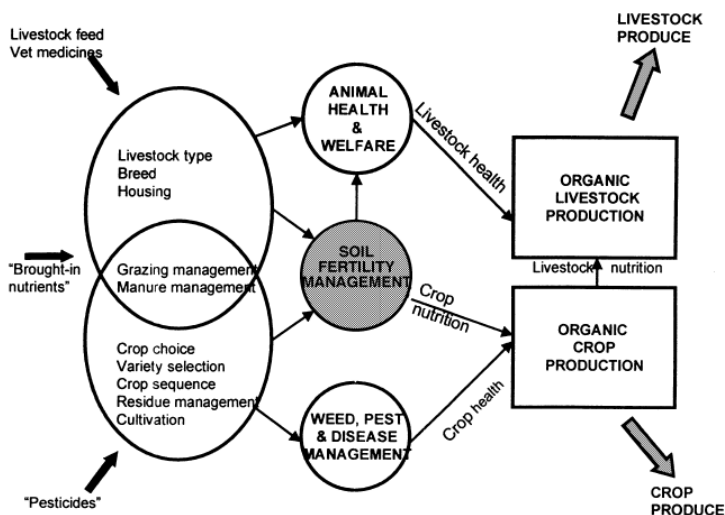


Fig. 2 The interactions between soil fertility and crop and animal productivity in organic farming systems. From Watson (Watson et al., 2002)

Details of modern breeding methods, (except genetic engineering itself, which is rejected unanimously) are still controversial in their acceptance in the organic world: Whereas IFOAM agrees to tissue culture and DNA diagnostic methods (including marker gene breeding) (IFOAM, 2004a), these the rules do not take position in radiation mutation breeding – no wonder, when one realizes that many well introduced cash crop traits have undergone this method in the past: other views on organic farming are much more strict and exclude those aforementioned methods:

The main rules for the Swiss organic agriculture for plants are as follows

http://www.admin.ch/ch/d/sr/c910_18.html

- natural cycles and processes are respected
- the use of chemical – synthetic substances are avoided
- the use of GMOs is not allowed, nor their derivatives, exception: products for veterinary medicine
- the products shall not be treated with radiation, and no products having undergone irradiation shall be used
- Many more details can be seen on the official website of the Swiss office of environment, see link above.

Another, breeding related controversy is the one on hybrid crops: Whereas many organizations on organic agriculture accept hybrid maize, since this is an agricultural fact which cannot be reversed easily, most are opposed against the introduction of more hybrid traits for other crops.

In summary, organic farming has its strong roots in traditional knowledge, but is building more and more on scientific research, a balance, which will keep discussions within the organic movement running and lively, especially when one realizes the wide spectrum of organic/ecological farming from extreme forms of biodynamic farming over mainstream organic and integrated farming to agro-ecological farming in all its variants.

5. Definition of Biotechnology Based Agriculture

The definition could be very simple, all agriculture is falling under this category, as long as there are transgenic crops involved. But this is rather too simplistic, since it does not reflect the goal and motivation behind the researchers who worked out this new and elegant breeding technology – which is clearly to reduce energy and pesticide input and enhance thus biodiversity, also taking care to enhance soil fertility by a rapid introduction of no-tillage.

5.1. About the differences between transgenic and non-transgenic crops on the molecular level:

(Van Bueren et al., 2003) try to explain on the molecular level, why organic farming cannot accept genetic engineering with a number of arguments:

Following (Verhoog et al., 2003), they state that the naturalness of organic agriculture not only to the avoidance of inorganic, chemical inputs and to the application of other agroecological principles, but also implies integrity. Their definition of intrinsic integrity of plant genomes:

The general appreciation for working in consonance with natural systems in organic farming extends itself to the regard with which members of the movement view individual species and organisms. Species, and the organisms belonging to them, are regarded as having an intrinsic integrity. This integrity exists aside from the practical value of the species to humanity and it can be enhanced or degraded by management and breeding measures. This kind of integrity can only be assessed from a biocentric perspective (see below). Organic agriculture assigns an ethical value to this integrity, and encourages propagation, breeding, and production systems that protect or enhance it.

And further on:

“From a biocentric perspective, organic agriculture acknowledges the intrinsic value and therefore the different levels of integrity of plants as described above. The consequence of acknowledging the intrinsic value of plants and respecting their integrity in organic agriculture implies that the breeder takes the integrity of plants into account in his choices of breeding and propagation techniques. It implies that one not merely evaluates the result and consequences of an intervention, but in the first place questions whether the intervention itself affects the integrity of plants. From the above described itself affects the integrity of plants.”

From the above described levels of the nature of plants and its characteristics, a number of criteria, characteristics, and principles for organic plant breeding and propagation techniques are listed by the authors for exclusion: All breeding methods using chemicals or radiation, such as colchicizing or gamma radiation induced mutants, all methods not allowing a full live cycle of the plant, all methods manipulating the genome of the organisms etc.

Unfortunately, the authors completely miss the point that the structure and assembly of DNA has been changed heavily over the decades and centuries of traditional breeding. Modern wheat in all variants and traits used today – also by organic farmers – are a product of processes, where the intrinsic value of the genomic naturalness has been completely ignored and any imaginable change has been successfully integrated, from adding chromosome fragments to integrating foreign genomes and accepting radiation mutation in the case of *Triticum durum* over a long period of time, also chromosome inversions, translocations are well documented in most major crops. The reality is, whether we accept it for any kind of definition, that most of the principles advocated by (Van Bueren & Struik, 2004, 2005; Van Bueren et al., 2002; Van Bueren et al., 2003; Verhoog et al., 2003) are clearly violated by almost all existing modern crop traits and cannot be redone, unless you could theoretically go back to the ancestral traits (which have in most cases of the major crops not survived the centuries of classical breeding efforts). So, in reality, the principle of the ‘intrinsic values of the plant genome’ is a fiction and not science based.

The whole concept of violation of the intrinsic naturalness of the genome by inserting alien genes from other species across the natural species barrier is also falsified by the occurrence of a naturally transgenic grass: See the case discussed by (Ghatnekar et al., 2006) in chapter 6.2 paragraph 2).

It is also questionable to stress the overcoming of natural hybridization barriers by genetic engineering, since this has been done by traditional breeding methods in former decades: Here the example of Somatic hybridising (i.e. non-sexual fusion of two somatic cells). The advantage of this method is that by the fusion of cells with different numbers of chromosomes (for instance different species of Solanum) fertile products of the crossing can be obtained at once because diploid cells are being somatically fused. Polyploid plants are obtained containing all the chromosomes of both parents instead of the usual half set of chromosomes from each. For this, cells are required whose cell walls have been digested away by means of enzymes and are only enclosed by a membrane, (these are then called protoplasts). With the loss of their cell walls, protoplasts have also lost their typical shape and are spherical like egg cells. This mixture of cells to be fused is then exposed to electric pulses. In order to get from the cell mixture the 'right' product of the fusion (since fusion of two cells from similar plants can also occur) one different selectable character in each of the original plants is necessary. Only cells that survive this double selection are genuine products of fusion. (The easiest way to achieve such selectable markers is by genetic engineering, for instance by incorporating antibiotic resistance into the original plants.) Protoplast fusion has been investigated and applied to potatoes, for instance. In the EU regulations concerning the deliberate release of genetically modified organisms into the environment somatic hybrids are not considered as GMO's and do not require authorization. The most recent draft of the EU organic regulations in which the introduction of GMO's in organic cultivation is forbidden, follows the above definition. (Karutz, 1999; Koop et al., 1996).

The concept of violated intrinsic naturalness of the genomes by transgenity is also falsified by the publications of Arber:

According (Nobel Laureate 1978) compared designed genetic alterations (including genetic engineering) with the spontaneous genetic variation known to form the substrate for biological evolution (Arber, 2002): "Site-directed mutagenesis usually affects only a few nucleotides. Still another genetic variation sometimes produced by genetic engineering is the reshuffling of genomic sequences, e.g. if a given open reading frame is brought under a different signal for expression control or if a gene is knocked out. All such changes have little chance to change in fundamental ways, the properties of the organism. In addition, it should be remembered that the methods of molecular genetics themselves enable the researchers anytime to verify whether the effective genomic alterations correspond to their intentions, and to explore the phenotypic changes due to the alterations. This forms part of the experimental procedures of any research seriously carried out. Interestingly, naturally occurring molecular evolution, i.e. the spontaneous generation of genetic variants has been seen to follow exactly the same three strategies as those used in genetic engineering. These three strategies are:

- (a) small local changes in the nucleotide sequences,
- (b) internal reshuffling of genomic DNA segments, and
- (c) acquisition of usually rather small segments of DNA from another type of organism by

horizontal gene transfer. However, there is a principal difference between the procedures of genetic engineering and those serving in nature for biological evolution. While the genetic engineer pre-reflects his alteration and verifies its results, nature places its genetic variations more randomly and largely independent of an identified goal. Under natural conditions, it is the pressure of natural selection which eventually determines, together with the available diversity of genetic variants, the direction taken by evolution. It is interesting to note that natural selection also plays its decisive role in genetic engineering, since indeed not all pre-reflected sequence alterations withstand the power of natural selection. Many investigators have experienced the effect of this natural force which does not allow functional disharmony in a mutated organism."

See also (Arber, 2000, 2003, 2004) in writings which confirm this important comparison on the genomic level of evolutionary and modern plant breeding processes. But there is of course, despite all the similarities, one major difference: whereas natural mutation acts completely in a natural time scale, that is, the mutants will need hundreds to hundred of thousands of years to overcome selective processes in nature until they really succeed and take over against their natural competitors, this is totally different with the transgenic crop products: they run through a R&D phase, and a regulatory process of an average of 15 to 20 years until being completely deregulated. But somewhere along this process they will be propagated to the millions in the field, covering in a evolutionary extremely short time span millions of hectares.

This basic insight of a molecular biologist has been confirmed by analysis of modern breeding processes and their real products in crops, as an example here a comparison on the genomic level between transgenic and non-transgenic wheat traits done by Shewry et al.: (Shewry et al., 2006):

“Whereas conventional plant breeding involves the selection of novel combinations of many thousands of genes, transgenesis allows the production of lines which differ from the parental lines in the expression of only single or small numbers of genes. Consequently it should in principle be easier to predict the effects of transgenes than to unravel the multiple differences which exist between new, conventionally-produced cultivars and their parents. Nevertheless, there is considerable concern expressed by consumers and regulatory authorities that the insertion of transgenes may result in unpredictable effects on the expression of endogenous genes which could lead to the accumulation of allergens or toxins. This is because the sites of transgene insertion are not known and transgenic plants produced using biolistics systems may contain multiple and rearranged transgene copies (up to 15 in wheat) inserted at several loci which vary in location between lines (Barcelo et al., 2001; Rooke et al., 2003). Similarly, this apparently random insertion has led to the suggestion that the expression of transgenes may be less stable than that of endogenous genes between individual plants, between generations and between growth environments. Although there is evidence that the expression of transgenes introduced by biolistic transformation is prone to silencing in a small proportion of wheat (Anand et al., 2003; Howarth et al., 2005), many recent reviews including, (Altpeter et al., 2005; Jones, 2005; Kohli et al., 2003; Sahrawat et al., 2003) demonstrate the utility of biolistics transformation (and other methods such as direct insertion of DNA fragments as a basis for stable genetic manipulation.”

(Baker et al., 2006; Barcelo et al., 2001) are confirming the above statements – they could be extended to other methods of transformation like direct insertion of DNA fragments (Paszowski et al., 1984) and with some questions about the long term stability also to the agrobacterium mediated transformations (Maghuly et al., 2007). But what is really interesting us here is published and documented by (Baudo et al., 2006): Overall, genome disturbances in traditional breeding in comparable cases are measured to be greater than in transformation.

“Detailed global gene expression profiles have been obtained for a series of transgenic and conventionally bred wheat lines expressing additional genes encoding HMW (high molecular weight) subunits of glutenin, a group of endosperm-specific seed storage proteins known to determine dough strength and therefore bread-making quality. Differences in endosperm and leaf transcriptome profiles between untransformed and derived transgenic lines were consistently extremely small, when analyzing plants containing either transgenes only, or also marker genes. Differences observed in gene expression in the endosperm between conventionally bred material were much larger in comparison to differences between transgenic and untransformed lines exhibiting the same complements of gluten subunits. These results suggest that the presence of the transgenes did not significantly alter gene expression and that, at this level of investigation, transgenic plants could be considered substantially equivalent to untransformed parental lines.”

The consequences are, that organic farming – using the argument of artificial DNA breeding disturbance, should decide for the transgenic crops in many cases. Another consequence is that transgenic crops of the first generation should never have been subjected to regulation purely based on methodology, rather it would have been wise to have in each case a close look at the products. In the case of the Golden Rice this has serious ethical consequences, because each year lost to unreasonable and unscientific regulation causes the death of hundreds of thousands of deaths due to severe deficiency in vitamin A, especially among the children of developing countries of South Eastern Asia. In Europe this kind of unscientific regulatory basis hinders the development of transgenic crop breeding for the benefit of a more ecological production. And on top of this the organic farming industry does not shy away from false and often hypocryt propaganda against genetically engineered crops for the sake of marketing their own products.

5.2. Modern trends in Ag-Biotech

No doubt, definitions on modern Ag-Biotech are also closely related to the green revolution, a term coined by William Gaud in a 1968 meeting of USAID, and launched as an extremely successful agricultural

movement, with the help of new crops, and improved irrigation, introducing fertilizers and pesticides and installing a consequent mechanization: the yield dramatically went up, particularly in Asia.

Thus, the pathway for the green revolution involved genetically altered plant forms, i.e. dwarf and semi-dwarf, where stem size height was lowered, but panicles not reduced in size, and seed production). But it made also necessary the application of high doses of chemical fertilizers and copious irrigation. Their luxuriant growth attracted a variety of pests, and therefore, chemical pesticides needed to be periodically applied. In addition, the new crops were also selected for photo insensitivity, so that they can be fitted into multiple cropping sequences. It is only later that the movement of the green revolution also adopted transgenic crops, a world wide success documented every year by www.isaaa.org.

Two names are linked to this green revolution with all its incomparable success: Norman Borlaug (Peace Nobel Prize 1970) (Borlaug et al., 1969; Reynolds & Borlaug, 2006a, b) and Monkombu Sambasivan Swaminathan, World Food Prize Laureate 1987 (Swaminathan, 1968a; Swaminathan, 1968b, 1972, 1998; Swaminathan, 2006).

Evenson and Gollin (Evenson & Gollin, 2003) came up in a thorough assessment of the Green Revolution with the following summary: Over the period 1960 to 2000, international agricultural research centers, in collaboration with national research programs, contributed to the development of “modern varieties” for many crops. These varieties have contributed to large increases in crop production. Productivity gains, however, have been uneven across crops and regions. Consumers generally benefited from declines in food prices. Farmers benefited only where cost reductions exceeded price reductions.

Very early, (Swaminathan, 1968a) warned from 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.”

After the unique success of the Green Revolution detrimental effects (upsurge of pest insects, growing insect resistance against widely used pesticides and negative effects on the soil fertility, Swaminathan called for an Evergreen Revolution already in 1968 and 1990 (Kesavan & Swaminathan, 2006; Swaminathan, 2006).

Unfortunately, the culmination of the benefit of free electricity to the farmers to draw groundwater for irrigation, absence of legumes in the crop rotation, and indiscriminate application of chemical fertilizers and pesticides led to the degradation of soil and water. The damage to the ecological foundations essential for sustainable advances in productivity led to the onset of a fatigue in the green revolution.

Lessons drawn from the green revolution are that steps taken towards productivity enhancement should concurrently address the conservation and improvement of soil, water, biodiversity, atmosphere, renewable energy sources, etc. Keeping these in focus, the goal of ‘*evergreen revolution*’ – for achieving higher productivity in perpetuity was developed. What this means is a system of agriculture that involves sustainable management of natural resources and progressive enhancement of soil quality, biodiversity and productivity.

Biotechnology has proven to be helpful to contribute to the evergreen revolution, since it helps to enhance some ecological factors, some review papers give lots of facts about this statement (Ammann, 2005; Cerdeira & Duke, 2006; Fawcett et al., 1994; Sanvido et al., 2006). Biotechnology has proven to reduce pesticide use, having positive influence on non-target insect populations helped to introduce no-tillage management beneficial to soil fertility: Several scientific studies give prove of those benefits for soil fertility (Fawcett & Towery, 2002; Schier, 2006).

An example of new biodiversity strategies fostered by a company known for the production of pesticides has been published by (Dollaker, 2006; Dollaker & Rhodes, 2007): They propose to integrate crop productivity and biodiversity and report about pilot projects: It highlights the potential roles a plant science company can play in addressing the challenge of jointly achieving crop productivity and biodiversity conservation objectives. These relate to activities that integrate biodiversity conservation objectives into technology research and development (R&D) of crop protection products and into land management

approaches. Three pilot initiatives developed by Bayer CropScience in Brazil, Guatemala and the UK in collaboration with a variety of local stakeholders illustrate how conservation objectives can be embedded in land management practices that sustainably enhance agricultural productivity and profitability, simultaneously addressing food security and biodiversity conservation challenges.

A modern variant of industrial farming is developing rapidly in the United States: Its called Precision Farming, it's a management system based mainly on satellite monitoring, it helps saving energy and time and can lead to a more ecological farming with higher yield (Godwin et al., 2003; Leithold & Traphan, 2006; Thenkabail, 2003). But the satellite supported surveillance systems can also be used for a further intensification of agriculture, which is basically unwelcome. Methods of precision farming, applied in an acceptable manner, do not directly contradict the main rules in organic farming and should seriously be considered as helpful auxiliary method.

6. Conclusions

All agricultural systems must include the ability to provide an economic return to the farmer, unprofitable agricultural systems will not survive unless they are heavily subsidized as in the United States or in Europe which in the long run is problematic for many reasons. Today's farming systems must provide opportunities to produce more food on smaller areas.

Related to this imperative are issues concerned with maintaining and enhancing output, such as soil fertility and reducing losses to weeds and pests. It is less easy to argue that a natural or diverse ecosystem is a critical input to a sustainable agricultural system.

While ecologists frequently stress the inter-relationships between species, it is difficult to see how the existence of species such as the swallow-tail butterfly or a rare orchid could contribute to a farming system's sustainability (Walker & Langridge, 2002). The degree of redundancy in ecological communities is largely unknown, and remains a rich field of investigation for ecologists. Agricultural systems can benefit from a higher biodiversity (not necessarily within the production surface) by presenting in the near vicinity of the production fields biological networks hosting highly diverse arthropod populations, which make the whole region more resistant to rapid pest invasions (Nentwig, 1999; Wood & Lenne, 2006).

This is not to say that agriculture could continue in the absence of all non-farmed species. Rather, there is a suggestion that only a subset of all existing species are essential for food and fiber production (Edwards-Jones & Howells, 2001; Walker, 1992).

We must also have a closer look at sustainability in farming systems, before we draw more conclusions:

6.1. About sustainability in farming systems

Sustainability definitions are manifold, some concentrate alone on ecological factors such as the views of the FAO (Narain, 2001), including management factors only. The question here is whether organic farming or biotech farming is more sustainable, the answer is not clear, since often the comparison does not have the same basic elements involved. Apart from all the debates, it should always involve crop-livestock systems – as crop residues can be put to value by surmounts over feeding into meat and milk while manure can be put to value as crop fertilization.

Here an example, which does not fit into the common view: In a thoughtful study, (Edwards-Jones & Howells, 2001) come to the conclusion, that organic farming systems are not sustainable in the strictest sense, although often claimed. Considerable amounts of energy are put into organic farming systems, the majority of the compounds utilized in crop protection are derived from non-renewable sources and incur processing and transport costs prior to application. Nevertheless, the long term balance of input is clearly favoring organic farming systems according to a 21years field trial in Switzerland: (Mader et al., 2002a, b, c) and (Goklany et al., 2002) whereas nutrient input (N, P, K) in the organic systems seems to be 34 to 51% lower than in the conventional systems, mean crop yield was only 20% lower over a period of 21 years, indicating on balance an efficient production. In the organic systems, the energy to produce a crop dry matter unit was 20 to 56% lower than in conventional and correspondingly 36 to 53% lower per unit of

land area. This might look again different in a comparison with an agriculture using biotech crops reducing pesticide use.

On the other hand, many of the 'biopesticides' (a nomenclature which implies falsely their benign low impact on natural systems) – compounds which are used to control pests - are not without toxicological hazards to ecology or humans. As an example, there are a number of research groups working on the difficult question on how to avoid or at least reduce the input of copper sulphate as a biopesticide. It is clear from some studies, that copper deposited in high concentrations has a negative impact on soil microbes. (Pedersen et al., 1999) found that total micro-arthropod abundance was highest at intermediate copper concentrations, and linearly related to grass biomass. For single species populations no clear picture of abundance in relation to soil copper was seen, but two collembolan species, *Folsomia quadrioculata* and *Folsomia fimetaria*, were among the most sensitive. The resulting Shannon-Wiener index of biodiversity decreased linearly with increasing soil copper concentrations. Those results imply that a short term strategy will be to avoid high concentrations of copper in the soil, but in the long run it will be better to avoid copper sulfate as a biopesticide altogether.

Sustainability can also be measured on a larger scale with a method developed in Europe in relation to landscape quality (Clemetsen & van Laar, 2000), the results need to be verified, but show positive influence of organic farming in Norway. What we can learn from this is the fact that sustainability on all kinds of farming strategies depends on the local circumstances and cannot be subject to overall categorization. It certainly depends also on the weight you give to specific factors of sustainability, and in the authors view population size and feeding the growing number of people should have a very high priority on this scale.

Again, the claim is made that traditional knowledge can contribute in an important way to develop sustainable practices in agriculture and silviculture (Duffield et al., 1998).

6.2. Biodiversity and farming systems

General remarks:

One should distinguish between overall biodiversity in the given farming landscape system including the production area and biodiversity within the production system itself, the fields. The latter is often illusionary, also for principle reasons: Weeds within the harvested fields are to be avoided, either by old-fashioned tilling or by various environmentally acceptable herbicides. The reason: For example in wheat production systems some of the weeds cherished by conservationists such as *Agrostemma githago* are highly toxic because of their saponin and githagenin-content and can spoil the harvested grain in low quantities already (Firbank, 1988).

But this is not the whole story:

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). 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 examples: Wild species: *Picea abies*, *Spartina townsendii*, *Sorghum verticilliflorum*, *Phragmites communis*, and *Pteridium aquilinum*. Early 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), *Oryza* (Harlan, 1989) described and illustrated harvests from dense stands of wild rice in Africa (*Oryza barthii*, 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. *dicocoides*) '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/ m².

We should also seriously rethink the view of many agrobiologists to uncritically accept the concept of the apparent loss of genetic diversity following the introduction of high-yielding Green Revolution wheat and rice varieties in the 1960s and 1970s, the same in the wake of the rapid adoption of superior GM crops today.

Some reasons for caution:

1) In ancient times there is evidence for genetic simplifications. According to the analysis of (Fedoroff, 2003) this is not a new phenomenon, already thousands of years ago maize underwent streamlining of its genome. This phenomenon occurs often in weeds, like the Chenopod *Atriplex prostrata*, and contribute to explain their exceptional exploiting migration ability since the Last Glacial Maximum of 18,000 radiocarbon years ago (Mulder, 1999). Genetic modifications have always been common, natural phenomena in geological time scales. Recently a natural transgenic plant has been discovered: The introgression of a functional nuclear gene from *Poa* to *Festuca ovina* has been discovered by (Ghatnekar et al., 2006).

2) We can also paradoxically encounter an enhancement in genetic diversity in modern soybean breeding: For example, (Sneller, 2003) looked at the genetic structure of the elite soybean population in North America, using coefficient of parentage (CP) analysis. Whereas the common sense would tell us, that soybean genetic diversity has diminished considerably in the wake of genetic engineering, there are hard data proving that its not so simple – on the contrary, genetic diversity can also be enhanced through the introduction of herbicide tolerant traits: The introduction of herbicide tolerant cultivars with the Roundup Ready ® trait was shown to have had little effect on soybean genetic diversity because of the widespread use of the trait in many breeding programs. Only 1% of the variation in CP among lines was related to differences between conventional and herbicide tolerant lines, while 19% of the variation among northern lines and 14% of the variation among southern lines was related to differences among the lines from different companies and breeding programs.

3) In more simple numbers of soybean traits: the new management freedom with the herbicide tolerant soybeans allowed for a more liberal use of varieties, most of them transgenic (Tylka, 2002). He listed nearly 400 nematode-resistant varieties of soy bean from 48 seed companies and five universities. All but seven of the varieties listed contain nematode resistance derived from a certain breeding line PI 88788. Of the varieties listed, 286 are resistant to the herbicide Roundup, six are tolerant to sulfonylurea herbicides, and the remainders are conventional, nonherbicide-resistant varieties.

4) Similarly, when (Bowman et al., 2003), examined genetic uniformity among cotton varieties in the United States, they found that genetic uniformity had not changed significantly with the introduction of transgenic cotton cultivars. In fact, when they compared the years before and after the introduction of transgenic cultivars, they observed that both the percentage of the crop planted to a small number of cultivars and the percentage planted to the most popular cultivar had declined. Thus genetic *uniformity* actually decreased by 28% over the period of introduction of transgenic cultivars. In the light of those data, the theoretical concepts of (Gepts & Papa, 2003) that GM crops should be held responsible for a biodiversity decline within crops are not very convincing. It remains to be said that the continued use of

locally adapted traits gained in traditional breeding should play an important role, more important than today (Swaminathan, 1968b, 1998), with special reference to India.

5) Similarly, (Witcombe, 1999) comes to the same conclusion: In areas that already grow modern cultivars, continued genetic improvement does not necessarily lead to loss of genetic diversity. Indeed, in many cases it leads to an increase in diversity, particularly when participatory methods and more innovative plant breeding strategies are employed.

It is clear from scientific reviews (Ammann, 2005; Miller, 2007; Sanvido et al., 2006) that the negative impact of modern biotech agriculture on biodiversity has been overestimated – more – it has been clearly overstated by the organic farmer community for the purpose of short sighted marketing. It becomes clear, that contrary to those negative views, there are many beneficial effects stemming from no-tillage and lowering pesticide amounts applied to the fields. There are numerous studies which give evidence, that adapted use of biotechnology crops can enhance biodiversity.

But there are also many studies which show that organic farming has a definite advantage compared with traditional agriculture regarding biodiversity. In an extensive review Hole et al. 2005 (Hole et al., 2005) cite many field studies showing that a wealth of evidence now points to unthoughtful agricultural intensification as the principal cause of the widespread declines in European farmland bird populations (Donald et al., 2001; Krebs et al., 1999 link WOS; Robinson & Sutherland, 2002) and the reduction in abundance and diversity of a host of plant and invertebrate taxa over the past decades are particularly well documented (Donald, 1998; Preston et al., 2002 link; Wilson et al., 1999 link, WOS). The main causes have been identified clearly: Overuse of broadband pesticides (Polaszek et al., 1999), overuse of fertilizers, mechanization disturbing soil and ground birds, exclusive use of large scale monocultures, empty landscapes stripped of hedges etc.

Only a few studies like Cobb et al. 1999 have sought to integrate the changes in soil conditions, biodiversity and socio-economic welfare linked to the conversion from non-organic to organic production (Cobb et al., 1999). Its conclusions may not be representative for all organic conversions, but the findings are of relevance at a time of debate over changing patterns of subsidies and other incentives in agricultural policy. The study showed that there were demonstrable differences in overall environmental conditions in the comparison of organic and non-organic farming, showing evidence of increased regional species diversity, and an eventual improvement in the profitability of the organic farming regime. The study also showed that variations in farm management practice strongly influence the notion of on-farm and off-farm environmental consequences.

The same positive effects of organic farming are shown in the long term study of 21 years in Switzerland (the so called DOK study (Fliessbach et al., 2000): Part of the data have further been published in Science (Mader et al., 2002b). The organic farming benefits related to biodiversity are well documented, especially with soil microbial diversity: Root length colonized by mycorrhizae in organic farming systems was 40% higher than in conventional systems (Fliessbach & Mader, 2000). Biomass and abundance of earthworms were higher by a factor of 1.3 to 3.2 in the organic plots as compared with conventional (Pfiffner & Mader, 1997). This all comes along with the fact, that yield is, compared to traditional farming, dropping 20%. This triggered a debate in Science, whether such a drop in yield is tolerable in the view of the protection of biodiversity, since today we should realize the imperative to produce more food on a shrinking amount of arable land (Goklany et al., 2002; Mader et al., 2002a, b). Potato yields in the organic systems were 58 to 66% of those in the conventional plots, mainly due to low potassium supply and the incidence of *Phytophthora infestans*. Winter wheat yields in the third crop rotation period reached an average of 4.1 metric tons per hectare in the organic systems. This corresponds to 90% of the grain harvest of the conventional systems. In an overall comparison, provided the lower energy input is also taken into account, one can theoretically conclude that in some favorable conditions organic farming can be the more efficient production strategy. A rather negative point is the safety of organic food: infections with the infamous *Echerichia coli* O157-H7 with its sometimes deadly consequences seem to be problem in organic food, some papers demonstrate the factual situation (Blaise et al., 2006; Islam et al., 2004a, 2005; Islam et al., 2004b; Lienert et al., 2003; Mukherjee et al., 2004; Mukherjee et al., 2006).

There are only a very few studies concentrating on a circumscribed agricultural practice and comparing organic and biotech farming, such as (Roush, 1994). This early paper compares directly Bt sprays used in organic farming and Bt transgenic crops, and the case is clear: Bt transgenic crops have advantages.

Also it has to be said, that studies on detailed impact of organic farming on various environmental factors are still scarce.

7. The consequences

The logical continuation of the above lines and views would be to refrain from nursing the divide between an agriculture using transgenic crops and management systems excluding them. It is plainly wrong to advocate this divide along the lines of breeding technologies or the use of agro-chemicals. This divide is caused by seemingly big differences in world views which are built, as demonstrated, on unfounded theory, near religious belief and false arguments. A really good solution and successful integration of present day management systems needs a new communication strategy, as specified in the preface. This strategy should embrace a dialogue with the public along the lines of the 'Three E – Strategy' (Entertainment, Emotion and Education) according to (Osseweijer, 2006a, b), which could initiate a decision making process going along the lines of the 'Systems Approach', a discursive decision making process (Ammann & Papazova Ammann, 2004). But this will not really create the agricultural management systems which build on local conditions, help efficiently in poverty alleviation, respecting elements of traditional knowledge and combine it in a successful way with science. Building those bridges in reality needs more than gaining public acceptance, more than decision making processes, it needs real decisions and carrying through these decisions. It needs the initiation of *participatory projects*, such as proposed by (Slingerland et al., 2006), who's working team from Wageningen started a participatory project in Ouagadougou in West Africa with sorghum: Fighting iron-deficiency malnutrition in West Africa became an interdisciplinary programme based on the food-chain approach. In Africa current interventions are dietary diversification, supplementation, fortification and biofortification. But such interventions alone have only moderate chances of success due to low purchasing power of households, lack of elementary logistics, lack of central processing of food and the high heterogeneity in production and consumption conditions. Slingerland et al. 2003 proposed based on excellent theoretical views (Slingerland et al., 2003) a staple food-chain approach, integrating parts of current interventions as an alternative. The research was carried out in several villages in Benin and Burkina Faso to take ecological, cultural and socio-economic diversity into account. The interdisciplinary approach aimed at elaborating interventions in soil fertility management, improvement and choice of sorghum varieties and food processing, to increase Fe and decrease the phytic acid-Fe molar ratio in sorghum-based foods. The phytic acid-Fe molar ratio was used as a proxy for Fe-bioavailability in food. Synergy and trade-offs resulting from the integrated approach showed its added value. P fertilization and soil organic amendments applied to increase yield were found to also increase phytic acid content of the grain and thus to decrease its nutritional value. Therefore, breeding to increase Fe needed to be followed by food processing to decrease phytols. We have to realize, that finally only a participatory approach, building on the unifying power of sustainable development will lead towards balanced choices between people, planet and profit in agricultural production chains and rural land use, in building the bridge between traditional knowledge and science. This will allow us to overcome a major problem in really integrating traditional knowledge: often the developing speed in introducing new technologies is too high and does not allow to integrate in a reasonable way all the valuable details of traditional knowledge.

The perspectives of the Golden Rice project <http://www.goldenrice.org/> and the project on the SuperSorghum www.supersorghum.org need both to take account of those thoughts in order to make them a real success. It is clear, that both projects include transgenic plants and thus need special efforts in participatory management in order to bring them to a successful end. It can be clearly envisaged, that synergies will be of considerable importance, as soon as we refrain from sterile fights over breeding and management methodologies and thus losing sight of target oriented best management decisions. In the face of the desperate situation in many countries of the developing world there is simply no time for sterile fights and a blatant overload of regulatory rules, which prevent for many years now the introduction of biofortified food such as the Golden Rice and soon also the biofortified Sorghum in many countries where every year tens of thousands of children are dying from vitamin A deficiency and Fe, Zn and protein malnutrition, making them dramatically and lethally vulnerable to such vulgar infectious diseases as the measles as one of many examples.

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Literature cited

Agrawal, A. (1995)

Dismantling the Divide between Indigenous and Scientific Knowledge. *Development and Change*, 26, 3, pp 413-439
<Go to ISI>://A1995RQ50100001 or comment: <http://home.case.edu/~ijd3/authorship/agrawal.html> AND <http://www.botanischergarten.ch/TraditionalKnowledge/Agrawal-Dismantling-1996.pdf>

Agrawal, D.P. (1997)

Traditional Knowledge Systems and Western Science. *Current Science*, 73, 9, pp 731-733
<Go to ISI>://A1997YG31900010 or <http://www.botanischergarten.ch/Bioprospecting/Agrawal-J-Int-Soc-1468-2451.00382.pdf>

Altieri, M. (1981)

Mixed Farming Systems. *Environment*, 23, 10, pp 5-&
<Go to ISI>://A1981MT05600003 AND <http://www.botanischergarten.ch/Organic/Altieri-Mixed-1981.pdf>

Altieri, M. (1992)

Classical Biological-Control and Social Equity - Reply. *Bulletin of Entomological Research*, 82, 3, pp 298-298
<Go to ISI>://A1992JX83300003

Altieri, M., Ines, C., & Nicholls, P.D. (1994, 2004)

Biodiversity and Pest Management in Agroecosystems International Book Distributing Co., IS: 10: 8181890787 pp

Altieri, M. & Nicholls, C.I. (2005)

Biodiversity and Pest Management in Agroecosystems, second edition, first Indian Reprint 2005, Army Printing Press edn. International Book Distributing Co., Lucknov, India, IS: 81-8189-078-7, pp 236

Altpeter, F., Baisakh, N., Beachy, R., Bock, R., Capell, T., Christou, P., Daniell, H., Datta, K., Datta, S., Dix, P.J., Fauquet, C., Huang, N., Kohli, A., Mooibroek, H., Nicholson, L., Nguyen, T.T., Nugent, G., Raemakers, K., Romano, A., Somers, D.A., Stoger, E., Taylor, N., & Visser, R. (2005)

Particle Bombardment and the Genetic Enhancement of Crops: Myths and Realities. *Molecular Breeding*, 15, 3, pp 305-327
<Go to ISI>://000228974300006

Ammann, K. (1999),

Electronic Source: Towards Precision Biotechnology (ed C. Juma), Viewpoints on Biotechnology published by: Center for International Development at Harvard University (CID), <http://www.cid.harvard.edu/cidbiotech/comments/comments38.htm>

Ammann, K. (2005)

Effects of Biotechnology on Biodiversity: Herbicide-Tolerant and Insect-Resistant Gm Crops. *Trends in Biotechnology*, 23, 8, pp 388-394

<Go to ISI>://000231342700005 and <http://www.sciencedirect.com/science/article/B6TCW-4GG2HJM-2/2/b23d0cc8c6846b9f6625162f3351b0ae> and <http://www.botanischergarten.ch/TIBTECH/Ammann-TIBTECH-Biodiversity-2005.pdf>

Ammann, K. & Papazova Ammann, B. (2004)

Factors Influencing Public Policy Development in Agricultural Biotechnology. *In Risk Assessment of Transgenic Crops*. (ed S. Shantaram), Vol. 9, pp. 1552. Wiley and Sons, Hoboken, NJ, USA.P. Christou & H. Klee Handbook of Plant Biotechnology,

<http://www.botanischergarten.ch/Wiley/Factors-Discourse-Wiley.pdf>

Anand, A., Trick, H.N., Gill, B.S., & Muthukrishnan, S. (2003)

Stable Transgene Expression and Random Gene Silencing in Wheat. *Plant Biotechnology Journal*, 1, 4, pp 241-251

<Go to ISI>://000188440000001

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,

Arber, W. (2000)

Genetic Variation: Molecular Mechanisms and Impact on Microbial Evolution. *Fems Microbiology Reviews*, 24, 1, pp 1-7

<Go to ISI>://000084915900001 AND <http://www.botanischergarten.ch/Mutations/Arber-Gen-Variation-FEMS-2000.pdf>

Arber, W. (2002)

Roots, Strategies and Prospects of Functional Genomics. *Current Science*, 83, 7, pp 826-828

<Go to ISI>://000178662800019 and <http://www.botanischergarten.ch/Mutations/Arber-Comparison-2002.pdf>

Arber, W. (2003)

Elements for a Theory of Molecular Evolution. *Gene*, 317, 1-2, pp 3-11

<Go to ISI>://000186667000002 and <http://www.botanischergarten.ch/Mutations/Arber-Gene-317-2003.pdf>

Arber, W. (2004)

Biological Evolution: Lessons to Be Learned from Microbial Population Biology and Genetics. *Research in Microbiology*, 155, 5, pp 297-300

<Go to ISI>://000222736200001 AND <http://www.botanischergarten.ch/Mutations/Arber-Evolution-Lessons-2004.pdf>

Atkinson, R., RA, Beachy, RN., Conway, G., Cordova, FA, Fox, MA, Holbrook, KA, Klessig, DF, McCormick, RL, McPherson PM, Rawlings III, HR, Rapson, R, Vanderhoef, LN, Wiley JD, Young CE. (2003)

Intellectual Property Rights: Public Sector Collaboration for Agricultural Ip Management. *Science*, 301, 5630, pp 174-175

<http://www.botanischergarten.ch/Patents/AtkinsonScience.pdf>

Atkinson, R.C., Beachy, R.N., Conway, G., Cordova, F.A., Fox, M.A., Holbrook, K.A., Klessig, D.F., McCormick, R.L., McPherson, P.M., Rawlings, H.R., Rapson, R., Vanderhoef, L.N., Wiley, J.D., & Young, C.E. (2003)

Public Sector Collaboration for Agricultural Ip Management. *Science*, 301, 5630, pp 174-175

<Go to ISI>://000184056200026

Baker, J.M., Hawkins, N.D., Ward, J.L., Lovegrove, A., Napier, J.A., Shewry, P.R., & Beale, M.H. (2006)

A Metabolomic Study of Substantial Equivalence of Field-Grown Genetically Modified Wheat. *Plant Biotechnology Journal*, 4, 4, pp 381-392

<Go to ISI>://000238256500002 AND <http://www.botanischergarten.ch/Organic/Baker-Metabolomics-2006.pdf>

Barcelo, P., Rasco-Gaunt, S., Thorpe, C., & Lazzeri, P. (2001)

Transformation and Gene Expression. In *Advances in Botanical Research Incorporating Advances in Plant Pathology* (eds P.R. Shewry, P.A. Lazzeri & K.J. Edwards), Vol. 34, pp. 59–126. J.A. Callow,

Baudo, M.M., Lyons, R., Powers, S., Pastori, G.M., Edwards, K.J., Holdsworth, M.J., & Shewry, P.R. (2006)

Transgenesis Has Less Impact on the Transcriptome of Wheat Grain Than Conventional Breeding. *Plant Biotechnology Journal*, 4, 4, pp 369-380

<Go to ISI>://000238256500001 AND <http://www.botanischergarten.ch/Organic/Baudo-Impact-2006.pdf>

Beachy, R.N. (2003)

Ip Policies and Serving the Public. *Science*, 299, 5606, pp 473-473

<Go to ISI>://000180559800001 and <http://www.botanischergarten.ch/Patents/BeachyScience.pdf>

Berkes, F., Berkes, M.K., & Fast, H. (2007)

Collaborative Integrated Management in Canada's North: The Role of Local and Traditional Knowledge and Community-Based Monitoring. *Coastal Management*, 35, 1, pp 143-162

<Go to ISI>://000242333800007

Berkes, F., Colding, J., & Folke, C. (2000)

Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications*, 10, 5, pp 1251-1262

<Go to ISI>://000089744800002 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Berkes-TK-Definition-2000.pdf>

Biber Klemm, S. & Cottier, T. (2006)

Rights to Plant Genetic : Resources & Tr Additional Knowledge, Basic Issues & Pers Pectives DEZA, World Trade Institute, CABI, pp 464

<http://www.lavoisier.fr/notice/fr282043.html>

Blaise, D., Ravindran, C.D., & Singh, J.V. (2006)

Trend and Stability Analysis to Interpret Results of Long-Term Effects of Application of Fertilizers and Manure to Cotton Grown on Rainfed Vertisols Doi:10.1111/J.1439-037x.2006.00222.X. *Journal of Agronomy and Crop Science*, 192, 5, pp 319-330

<http://www.blackwell-synergy.com/doi/abs/10.1111/j.1439-037X.2006.00222.x> AND <http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit-1/Blaise-Cotton-Longterm-2006.pdf>

Borlaug, N.E., Narvaez, I., Aresvik, O., & Anderson, R.G. (1969)

Green Revolution Yields a Golden Harvest. *Columbia Journal of World Business*, 4, 5, pp 9-19

<Go to ISI>://A1969Y496900005 AND <http://www.botanischergarten.ch/Organic/Borlaug-GreenRevolution-1969.pdf>

Bowman, D.T., May, O.L., & Creech, J.B. (2003)

Genetic Uniformity of the Us Upland Cotton Crop since the Introduction of Transgenic Cottons. *Crop Science*, 43, 2, pp 515-518

Brand, U. & Gorg, C. (2003)

The State and the Regulation of Biodiversity - International Biopolitics and the Case of Mexico. *Geoforum*, 34, 2, pp 221-233

<Go to ISI>://000183000100009 or <http://www.botanischergarten.ch/Geoforum/Brand-Geoforum-Mex.pdf>

CBD-SBSTTA (1999),

Electronic Source: Consequences of the Use of the New Technology for the Control of Plant Gene Expression for the Conservation and Sustainable Use of Biological Diversity, published by: CBD,

<http://www.biodiv.org/doc/meetings/sbstta/sbstta-04/official/sbstta-04-09-rev1-en.pdf>

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. *J. Environ. Qual.*, 35, pp 1633-1658

doi:10.2134/jeq2005.0378 AND <http://www.botanischergarten.ch/HerbizideTol/Cerdeira-Status-2006.pdf>

Clemetsen, M. & van Laar, J. (2000)

The Contribution of Organic Agriculture to Landscape Quality in the Sogn Og Fjordane Region of Western Norway. *Agriculture Ecosystems & Environment*, 77, 1-2, pp 125-141

<Go to ISI>://000084356400011

Cobb, D., Feber, R., Hopkins, A., Stockdale, L., O'Riordan, T., Clements, B., Firbank, L., Goulding, K., Jarvis, S., & Macdonald, D. (1999)

Integrating the Environmental and Economic Consequences of Converting to Organic Agriculture: Evidence from a Case Study. *Land Use Policy*, 16, 4, pp 207-221

<Go to ISI>://000083446800002 AND <http://www.botanischergarten.ch/Organic/Cobb-Integrating-1999.pdf>

Cohen, J.I. (2005)

Poorer Nations Turn to Publicly Developed Gm Crops. *Nature Biotechnology*, 23, 1, pp 27-33

<http://www.botanischergarten.ch/PublicSector-Danforth-20050304/Cohen-Naturebiotech-2005.pdf> AND <http://www.botanischergarten.ch/Developing/Cohen-Naturebiotech-2005.pdf>

Curci Staffler, J. (2003)

Towards a Reconciliation between the Convention on Biological Diversity and Trips Agreement. An Interface among Intellectual Property Rights on Biotechnology, Traditional Knowledge and Benefit Sharing, University of Geneva, Geneva Thesis, pp 108

<http://www.botanischergarten.ch/Patents/Staffler-CBD-TRIPS.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>

Dhlamini, Z., Spillane, C., Moss, J., Ruane, J., Urquia, J., & Sonnino, A. (2005).

Status of Research and Application of Crop Technologies in Developing Countries, Preliminary Assessment, FAO pp 62
FAO Reports Rome.

<http://www.botanischergarten.ch/FAO/Status-FAO-GMcrops-2005.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>

Donald, P.F., Green, R.E., & Heath, M.F. (2001)

Agricultural Intensification and the Collapse of Europe's Farmland Bird Populations. Proceedings of the Royal Society of London Series B-Biological Sciences, 268, 1462, pp 25-29

<http://www.botanischergarten.ch/Organic/Donald-Intensification-2001.pdf>

Donald, P.I., WOS (1998)

Changes in the Abundance of Invertebrates and Plants on British Farmland. British Wildlife, 9, pp 279–289

Duffield, C., Gardner, J.S., Berkes, F., & Singh, R.B. (1998)

Local Knowledge in the Assessment of Resource Sustainability: Case Studies in Himachal Pradesh, India, and British Columbia, Canada. Mountain Research and Development, 18, 1, pp 35-49

<Go to ISI>://000072195200004 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Duffield-Local-1998.pdf>

Edwards-Jones, G. & Howells, O. (2001)

The Origin and Hazard of Inputs to Crop Protection in Organic Farming Systems: Are They Sustainable? Agricultural Systems, 67, 1, pp 31-47

<Go to ISI>://000166429500003 AND <http://www.botanischergarten.ch/Organic/Edwards-Jones-Inputs-2001.pdf>

Evans, L.T. (1998)

Feeding the Ten Billion: Plants and Population Growth, Cambridge University Press, Cambridge, UK., pp p. 34

Evenson, R.E. & Gollin, D. (2003)

Assessing the Impact of the Green Revolution, 1960 to 2000. *Science*, 300, 5620, pp 758-762

<Go to ISI>://000182579800038

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. (2003)

Prehistoric Gm Corn. *Science*, 302, 5648, pp 1158-1159

<Go to ISI>://000186544300034 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Fedoroff-Prehistoric-Corn-2003.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>

Feyerabend, P. (1987)

Farewell to Reason Verso, London UK, pp

Firbank, L.G. (1988)

Agrostemma-Githago L. *Journal of Ecology*, 76, 4, pp 1232-1246

<Go to ISI>://A1988R996300022 AND <http://www.botanischergarten.ch/Weeds/Firbank-Weeds-1986.pdf>

Fliessbach, A. & Mader, P. (2000)

Microbial Biomass and Size-Density Fractions Differ between Soils of Organic and Conventional Agricultural Systems. *Soil Biology & Biochemistry*, 32, 6, pp 757-768

<Go to ISI>://000087495700003 AND <http://www.botanischergarten.ch/Organic/Fliessbach-Microbial-Biomass-2000.pdf>

Fliessbach, A., Mader, P., Dubois, D., Gunst, L., Stauffer, W., Fried, P., Pfiffner, L., Alföldi, T., & Niggli, U. (2000).

Organic Farming Enhances Soil Fertility and Biodiversity, Research Institute of Organic Agriculture, Federal Research Station for Agroecology and Agriculture pp 16 *Fibl Dossier 1*, Frick, Switzerland.

http://www.botanischergarten.ch/Organic/DOC_slim.pdf AND <http://www.botanischergarten.ch/Organic/DOC-slim-Slides.ppt>

Gepts, P. & Papa, R. (2003)

Possible Effects of Trans(Gene) Flow from Crops to the Genetic Diversity from Landraces and Wild Relatives. Environmental Biosafety Research, 2, pp 89-113

<http://www.botanischergarten.ch/Geneflow/Gepts&Papa2003.pdf>

Ghatnekar, L., Jaarola, M., & Bengtsson, B.O. (2006)

The Introgression of a Functional Nuclear Gene from *Poa* to *Festuca ovina*. Proceedings: Biological Sciences, 273, 1585, pp 395 - 399

<http://www.botanischergarten.ch/Mutations/Gathnekar-Transgen-Festuca.pdf>

Giannakas, K. (2003)

Infringement of Intellectual Property Rights: Developing Countries, Agricultural Biotechnology, and the Trips Agreement, Washington, pp 25 - 28

<http://www.ifpri.org/> or more detailed <http://www.ifpri.org/divs/eptd/dp/papers/eptdp80.pdf>

Girsberger, M. (1999)

Biodiversity and the Concept of Farmers' Rights in International Law; Factual Background and Legal Analysis 1 Peter Lang Publishing; (September 1, 1999), Bern, IS: 0820446300, pp 415

Godwin, R.J., Wood, G.A., Taylor, J.C., Knight, S.M., & Welsh, J.P. (2003)

Precision Farming of Cereal Crops: A Review of a Six Year Experiment to Develop Management Guidelines. Biosystems Engineering, 84, 4, pp 375-391

<Go to ISI>://000182703700002

Goklany, I., Mader P. et al., & Zobel, D. (2002)

Organic Farming and Energy Efficiency. Science, 298, 5600, pp 1890-1891

<Go to ISI>://000179629200016 AND <http://www.botanischergarten.ch/Organic/Zobel-Reply-2002.pdf> AND <http://www.botanischergarten.ch/Organic/Goklany-Maeder-Science-2002-p1890.pdf>

Guthman, J. (1998)

Regulating Meaning, Appropriating Nature: The Codification of California Organic Agriculture. Antipode, 30, 2, pp 135+

<Go to ISI>://000073772300004 AND <http://www.botanischergarten.ch/Organic/Guthman-Standards-1998.pdf>

Harlan, J. & Zohary, D. (1966)

Distribution of Wild Wheats and Barley. Science, 153, pp 1074-1080

Harlan, J.R. (1989)

Wild-Grass Harvesting in the Sahara and Sub-Saharan 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

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,

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, F., & Evans, A.D. (2005)

Does Organic Farming Benefit Biodiversity? *Biological Conservation*, 122, 1, pp 113-130

<Go to ISI>://000225522100012 AND <http://www.botanischergarten.ch/Organic/Hole-Organic-biodiversity-2004.pdf>

Horton, R. (1967a)

African Traditional Thought and Western Science .2. Closed and Open Predicaments. *Africa*, 37, 2, pp 155-187

<Go to ISI>://A1967ZB76700002 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Horton-Africa-2-1967.pdf>

Horton, R. (1967b)

African Traditional Thought and Western Science I: From Tradition to Science. *Africa*, 37, 1, pp 50-71

<Go to ISI>://A1967ZB76600003 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Horton-Africa-1-1967.pdf>

Howarth, J.R., Jacquet, J.N., Doherty, A., Jones, H.D., & Cannell, M.E. (2005)

Molecular Genetic Analysis of Silencing in Two Lines of *Triticum Aestivum* Transformed with the Reporter Gene Construct Pahc25. *Annals of Applied Biology*, 146, 3, pp 311-320

<Go to ISI>://000229519700005

IFOAM (2004a).

D1 Plant Breeding Draft Standards, IFOAM, International Federation of Organic Agricultural Movements pp 2 Bonn.

http://www.ifoam.org/about_ifoam/standards/norms/draft_standards/DraftPlantBreedingStandardsD1050729.pdf

IFOAM (2004b).

D2 Draft Biodiversity and Landscape Standards, IFOAM (International Federation of Organic Agriculture Movements pp 7 Bonn.

http://www.ifoam.org/about_ifoam/standards/norms/draft_standards/BiodiversityDraftStandardsD2050728.pdf

IFOAM (2004c).

D3 Resource Use Draft Standards, IFOAM (International Federation of Organic Agriculture Movements pp 7 Bonn.

http://www.ifoam.org/about_ifoam/standards/norms/draft_standards/ResourceUseDraftStandardsD3050728.pdf

IFOAM (2005).

Definition of Organic Agriculture, IFOAM, International Federation of Organic Agricultural Movements, proposals pp 12 Bonn.

http://www.ifoam.org/organic_facts/doa/pdf/Definition_of_Organic_Agriculture_Report.pdf

IFOAM (2007),

Electronic Source: Principles of Organic Farming (ed IFOAM),
Organic Agriculture Movements,

published by: IFOAM, International Federation of

http://www.ifoam.org/about_ifoam/principles/index.html

Islam, M., Doyle, M.P., Phatak, S.C., Millner, P., & Jiang, X.P. (2004a)

Persistence of Enterohemorrhagic Escherichia Coli O157 : H7 in Soil and on Leaf Lettuce and Parsley Grown in Fields Treated with Contaminated Manure Composts or Irrigation Water. *Journal of Food Protection*, 67, 7, pp 1365-1370

<Go to ISI>://000222559700006 AND <http://www.botanischergarten.ch/Organic/Islam-Fate-Ecoli-O157-H7-2004.pdf>

Islam, M., Doyle, M.P., Phatak, S.C., Millner, P., & Jiang, X.P. (2005)

Survival of Escherichia Coli O157 : H7 in Soil and on Carrots and Onions Grown in Fields Treated with Contaminated Manure Composts or Irrigation Water. *Food Microbiology*, 22, 1, pp 63-70

<Go to ISI>://000225615400008 AND <http://www.botanischergarten.ch/Organic/Islam-Survival-ColiO157H7-2005.pdf>

Islam, M., Morgan, J., Doyle, M.P., & Jiang, X.P. (2004b)

Fate of Escherichia Coli O157 : H7 in Manure Compost-Amended Soil and on Carrots and Onions Grown in an Environmentally Controlled Growth Chamber. *Journal of Food Protection*, 67, 3, pp 574-578

<Go to ISI>://000220077200024

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>

Johannes, R.E. (1989).

Traditional Ecological Knowledge: A Collection of Essays. pp Gland, Switzerland.

Jones, H.D. (2005)

Wheat Transformation: Current Technology and Applications to Grain Development and Composition. *Journal of Cereal Science*, 41, 2, pp 137-147

<Go to ISI>://000227308500001

Karutz, C. (1999).

Electronic Source: Ecological Cereal Breeding and Genetic Engineering, published by: Research Institute for Organic Agriculture (FiBL),,

<http://www.biogene.org/themen/saatgut/getengl.html#cont>

Kesavan, P.C. & Swaminathan, M.S. (2006)

From Green Revolution to Evergreen Revolution: Pathways and Terminologies. *Current Science*, 91, 2, pp 145-146

<Go to ISI>://000241623300001 AND <http://www.botanischergarten.ch/Organic/Kesavan-Evergreen-2006.pdf>

Kohli, A., Twyman, R.M., Abranches, R., Wegel, E., Stoger, E., & Christou, P. (2003)

Transgene Integration, Organization and Interaction in Plants. *Plant Molecular Biology*, 52, 2, pp 247-258

<Go to ISI>://000183204500001

Koop, H.U., Steinmuller, K., Wagner, H., Rossler, C., Eibl, C., & Sacher, L. (1996)

Integration of Foreign Sequences into the Tobacco Plastome Via Polyethylene Glycol-Mediated Protoplast Transformation. *Planta*, 199, 2, pp 193-201

<Go to ISI>://A1996UQ03400003

Krebs, J., Wilson, J., Bradbury, R., & Siriwardena, G. (1999 link WOS)

The Second Silent Spring ? *Nature*, 400, pp 611-612

Leithold, P. & Traphan, K. (2006)

On Farm Research (Ofr) - a Novel Experimental Design for Precision Farming. *Journal of Plant Diseases and Protection*, pp 157-164

<Go to ISI>://000243263500020

Levi-Strauss, C. (1962)

La Pensée Sauvage Plon, Paris, pp p. 269

Lienert, J., Haller, M., Berner, A., Stauffacher, M., & Larsen, T.A. (2003)

How Farmers in Switzerland Perceive Fertilizers from Recycled Anthropogenic Nutrients (Urine). *Water Science and Technology*, 48, 1, pp 47-56

<Go to ISI>://000185292800007 AND <http://www.botanischergarten.ch/Organic/Lienert-Urine-Acceptance-2003.pdf>

Mader, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002a)

The Ins and Outs of Organic Farming, Response to Goklany I. *Science*, 298, 5600, pp 1889-1890

<Go to ISI>://000179629200015

Mader, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002b)

Organic Farming and Energy Efficiency. *Science*, 298, 5600, pp 1891-1891

<Go to ISI>://000179629200017 AND <http://www.botanischergarten.ch/Organic/Maeder-Organicfarming-2002.pdf>

Mader, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002c)

Soil Fertility and Biodiversity in Organic Farming. *Science*, 296, 5573, pp 1694-1697

<http://www.botanischergarten.ch/Organic/Maeder-Science-2002-p1694.pdf>

Maghuly, F., da Câmara Machado, A., Leopold, S., Khan, M., Katinger, H., & Laimer, M. (2007)

Long-Term Stability of Marker Gene Expression in *Prunus Subhirtella*: A Model Fruit Tree Species. *Journal of Biotechnology*, 127, 2, pp 310-321

<http://www.botanischergarten.ch/Marker-Genes/Maghuly-Marker-2006.pdf>

Miller, H.I. (2007)

Biotech's Defining Moments. Trends in Biotechnology, 25, 2, pp 56-59

<http://www.sciencedirect.com/science/article/B6TCW-4MK0HGK-1/2/409c558b4630f54cdc689f843e290a6d> AND <http://www.botanischergarten.ch/Regulation/Miller-Regulation-2006.pdf>

Mukherjee, A., Speh, D., Dyck, E., & Diez-Gonzalez, F. (2004)

Preharvest Evaluation of Coliforms, Escherichia Coli, Salmonella, and Escherichia Coli O157 : H7 in Organic and Conventional Produce Grown by Minnesota Farmers. Journal of Food Protection, 67, 5, pp 894-900

<Go to ISI>://000221373600006 AND <http://www.botanischergarten.ch/Organic/Mukherjee-Preharvest-Coliforms-2004.pdf>

Mukherjee, A., Speh, D., Jones, A.T., Buesing, K.M., & Diez-Gonzalez, F. (2006)

Longitudinal Microbiological Survey of Fresh Produce Grown by Farmers in the Upper Midwest. Journal of Food Protection, 69, 8, pp 1928-1936

<Go to ISI>://000239541900022 AND <http://www.botanischergarten.ch/Organic/Mukherjee-Longitudinal-MicrobiolSurvey-2006.pdf>

Mulder, C. (1999)

Biogeographic Re-Appraisal of the Chenopodiaceae of Mediterranean Drylands: A Quantitative Outline of Their General Ecological Significance in the Holocene. Palaeoecology of Africa, 26, pp 161-188

Narain, P. (2001).

Agri-Environmental Indicators, Concepts and Frameworks Fao's Handbook on the Collection of Data and Compilation of Agri-Environmental Indicators, Statistical Commission and Economic Commission of Europe, Paper submitted by FAO. Working Paper No. 23 pp 9 Working Paper No. 23 Ottawa, Canada.

<http://www.unece.org/stats/documents/2001/10/env/wp.23.e.pdf> AND <http://www.botanischergarten.ch/FAO/FAO-Agri-Indic-Contents-wp.23.e.pdf>

Nentwig, W. (1999)

Weedy Plant Species and Their Beneficial Arthropods: Potential for Manipulation in Field Crops University of California Press, Berkeley, Los Angeles, London, pp

<http://www.zoology.unibe.ch/ecol/publ/abstracts/99-21.htm>

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

Ngoc Hai, N. (1998)

Organic Agriculture in Developing Countries Needs Modern Biotechnology Biotechnology and Development Monitor, 34, pp 24

<http://www.biotech-monitor.nl/new/index.php?link=publications>

Ohmagari, K. & Berkes, F. (1997)

Transmission of Indigenous Knowledge and Bush Skills among the Western James Bay Cree Women of Subarctic Canada. Human Ecology, 25, 2, pp 197-222

<Go to ISI>://A1997XG84900002

Osseweijer, P. (2006a)

Imagine Projects with a Strong Emotional Appeal. *Nature*, 444, 7118, pp 422-422

<Go to ISI>://000242215700018 AND <http://www.botanischergarten.ch/Ask-Force/Osseweijer-Nature-2007.pdf>

Osseweijer, P. (2006b)

A New Model for Science Communication That Takes Ethical Considerations into Account - the Three-E Model: Entertainment, Emotion and Education. *Science and Engineering Ethics*, 12, 4, pp 591-593

<Go to ISI>://000242181200002 AND <http://www.botanischergarten.ch/Ask-Force/Osseweijer-EEE-2006.pdf>

Paszkowski, J., Shillito, R.D., Saul, M., Mandak, V., Hohn, T., Hohn, B., & Potrykus, I. (1984)

Direct Gene-Transfer to Plants. *Embo Journal*, 3, 12, pp 2717-2722

<Go to ISI>://A1984TV16200001 AND <http://www.botanischergarten.ch/Transgenic/Paszkowski-Direct-1984.pdf>

Pedersen, M.B., Axelsen, J.A., Strandberg, B., Jensen, J., & Attrill, M.J. (1999)

The Impact of a Copper Gradient on a Microarthropod Field Community. *Ecotoxicology*, 8, 6, pp 467-483

<Go to ISI>://000087371400006 AND <http://www.botanischergarten.ch/Organic/Pedersen-Copper-Impact-1999.pdf>

Pfiffner, L. & Mader, P. (1997)

Effects of Biodynamic, Organic and Conventional Production Systems on Earthworm Populations. *Biological Agriculture & Horticulture*, 15, 1-4, pp 3-10

<Go to ISI>://000073531100002

Polaszek, A., Riches, C., & Lenné, J.M. (1999)

The Effects of Pest Management, Strategies on Biodiversity in Agroecosystems. *In Agrobiodiversity, Characterization, Utilization and Management* (eds D. Wood & J. Lenne), pp. 273-303. CABI Publishing, Oxon, UK and New York, NY, USA,

Popper, K. (1972)

Objective Knowledge, an Evolutionary Approach Clarendon Press, Oxford University Press., London, IS: 0-19-875024-2, pp 390

some chapters: <http://www.marxists.org/reference/subject/philosophy/works/at/popper.htm>

Popper, K. (1994)

Objektive Erkenntnis, Ein Evolutionärer Entwurf Campe Paperback, pp

Prain, D. (1903)

'Flora of the Sundribuns, pp 231–370, p 357.

Preston, C.D., Telfer, M.G., Arnold, H.R., Carey, P.D., Cooper, J.M., Dines, T.D., Hill, M.O., Pearman, D.A., Roy, D.B., & Smart, S.M. (2002 link).

The Changing Flora of the Uk., DEFRA pp.

Reijntjes, C.B., Haverkort, & Waters-Bayer, A. (1992)

Farming for the Future MacMillan Press Ltd, London, pp

Reynolds, M.P. & Borlaug, N.E. (2006a)

Applying Innovations and New Technologies for International Collaborative Wheat Improvement. Journal of Agricultural Science, 144, pp 95-110

<Go to ISI>://000237983900001

Reynolds, M.P. & Borlaug, N.E. (2006b)

Impacts of Breeding on International Collaborative Wheat Improvement. Journal of Agricultural Science, 144, pp 3-17

<Go to ISI>://000237785600002

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

Rooke, L., Steele, S.H., Barcelo, P., Shewry, P.R., & Lazzeri, P.A. (2003)

Transgene Inheritance, Segregation and Expression in Bread Wheat. Euphytica, 129, 3, pp 301-309

<Go to ISI>://000180749900007 AND <http://www.botanischergarten.ch/Organic/Rooke-Inheritance-2003.pdf>

Roush, R.T. (1994)

Managing Pests and Their Resistance to Bacillus-Thuringiensis - Can Transgenic Crops Be Better Than Sprays. Biocontrol Science and Technology, 4, 4, pp 501-516

<Go to ISI>://A1994QU28100016 AND <http://www.botanischergarten.ch/Bt/Roush-Bt-Sprays-1994.pdf>

Sahrawat, A.K., Becker, D., Lutticke, S., & Lorz, H. (2003)

Genetic Improvement of Wheat Via Alien Gene Transfer, an Assessment. Plant Science, 165, 5, pp 1147-1168

<Go to ISI>://000185805700026

Sanvido, O., Stark, M., Romeis, J., & Bigler, F. (2006).

Ecological Impacts of Genetically Modified Crops, Experiences from Ten Years of Experimental Field Research and Commercial Cultivation, Agroscope Reckenholz-Tänikon Research Station ART, Reckenholzstrasse 191, CH-8046 Zurich, Phone +41 (0)44 377 71 11, Fax +41 (0)44 377 72 01, info@art.admin.ch, www.art.admin.ch. 1 pp 108 ART-Schriftenreihe 1 Zürich Reckenholz.

<http://www.botanischergarten.ch/Environment/Sanvido-Agroscope-2006.pdf>

Schier, A. (2006)

Field Study on the Occurrence of Ground Beetles and Spiders in Genetically Modified, Herbicide Tolerant Corn in Conventional and Conservation Tillage Systems. Journal of Plant Diseases and Protection, 113, 3, pp 101-113

<Go to ISI>://000243263500014 AND <http://www.botanischergarten.ch/Bt/Schier-Comparison-2006.pdf>

Shewry, P.R., Powers, S., Field, J.M., Fido, R.J., Jones, H.D., Arnold, G.M., West, J., Lazzeri, P.A., Barcelo, P., Barro, F., Tatham, A.S., Bekes, F., Butow, B., & Darlington, H. (2006)

Comparative Field Performance over 3 Years and Two Sites of Transgenic Wheat Lines Expressing Hmw Subunit Transgenes. *Theoretical and Applied Genetics*, 113, 1, pp 128-136

<Go to ISI>://000238345000016 AND <http://www.botanischergarten.ch/Organic/Shewry-Performance-2006.pdf>

Slingerland, M.A., Klijn, J.A.E., Jongman, R.H.G., & van der Schans, J.W. (2003).

The Unifying Power of Sustainable Development. Towards Balanced Choices between People, Planet and Profit in Agricultural Production Chains and Rural Land Use: The Role of Science., Wageningen University pp 1-94 WUR-report Sustainable Development Wageningen.

<http://www.botanischergarten.ch/Discourse/Slingerland-Unifying-Power-2003.pdf>

Slingerland, M.A., Traore, K., Kayode, A.P.P., & Mitchikpe, C.E.S. (2006)

Fighting Fe Deficiency Malnutrition in West Africa: An Interdisciplinary Programme on a Food Chain Approach. *Njas-Wageningen Journal of Life Sciences*, 53, 3-4, pp 253-279

<Go to ISI>://000238275500002 <http://www.botanischergarten.ch/Africa-Harvest-Sorghum-Lit-1/Slingerland-Deficiency-Sorghum-2006.pdf> AND <http://www.botanischergarten.ch/Facultyof1000/Slingerland-F1000-2006.pdf>

Sneller, C.H. (2003)

Impact of Transgenic Genotypes and Subdivision on Diversity within Elite North American Soybean Germplasm. *Crop Science*, 43, 1, pp 409-414

Swaminathan, M.S. (1968a),

The Age of Algeny, Genetic Destruction of Yield Barriers and Agricultural Transformation. Presidential Address, Agricultural Science Section, Conference Location Proc. Indian Science Congr., 55th Indian Science Congr. Jan. 1968., Ed. pp

Swaminathan, M.S. (1968b)

Changing Concepts and Canvass of Plant Breeding. *Indian Journal of Genetics and Plant Breeding*, A 28, pp 7-&

<Go to ISI>://A1968F871700002

Swaminathan, M.S. (1972)

Agriculture Cannot Wait. *Current Science*, 41, 16, pp 583-&

<Go to ISI>://A1972N264500001 AND NEBIS

Swaminathan, M.S. (1998)

Genetic Resources and Traditional Knowledge: From Chennai to Bratislava. *Current Science*, 74, 6, pp 495-497

<Go to ISI>://000072890700003

Swaminathan, M.S. (2001)

Biotechnology, Genetic Modification, Organic Farming and Nutrition Security. *Phytomorphology*, 51, 3-4, pp 19-30

<http://cat.inist.fr/?aModele=afficheN&cpsidt=13881551> AND

<http://www.botanischergarten.ch/TraditionalKnowledge/Swaminathan-Biotech-Organic-2001.pdf>

Swaminathan, M.S. (2006)

An Evergreen Revolution. *Crop Sci* %R 10.2135/cropsci2006.9999, 46, 5, pp 2293-2303

<http://crop.scijournals.org/cgi/content/abstract/46/5/2293> AND <http://www.botanischergarten.ch/Organic/Swaminathan-Evergreen-2006.pdf>

Thenkabail, P.S. (2003)

Biophysical and Yield Information for Precision Farming from near-Real-Time and Historical Landsat Tm Images. International Journal of Remote Sensing, 24, 14, pp 2879-2904

<Go to ISI>://000184046300004

Turner, N.J. & Berkes, F. (2006)

Coming to Understanding: Developing Conservation through Incremental Learning in the Pacific Northwest. Human Ecology, 34, 4, pp 495-513

<Go to ISI>://000240981100003

Turner, N.J., Davidson-Hunt, I.J., & O'Flaherty, M. (2003)

Living on the Edge: Ecological and Cultural Edges as Sources of Diversity for Social-Ecological Resilience. Human Ecology, 31, 3, pp 439-461

<Go to ISI>://000184588200005

Turner, N.J., Ignace, M.B., & Ignace, R. (2000)

Traditional Ecological Knowledge and Wisdom of Aboriginal Peoples in British Columbia. Ecological Applications, 10, 5, pp 1275-1287

<Go to ISI>://000089744800005 AND <http://www.botanischergarten.ch/TraditionalKnowledge/Turner-TK-British-Columbia-2000.pdf>

Tylka, G.L. (2002)

Soybean Cyst Nematoderesistant Varieties for Iowa. Iowa State University, Ext. Publ. Pm-1649, 1649, pp 1-26

<http://www.extension.iastate.edu/Publications/PM1649.pdf>

Van Bueren, E.T.L. & Struik, P.C. (2004)

The Consequences of the Concept of Naturalness for Organic Plant Breeding and Propagation. Njas-Wageningen Journal of Life Sciences, 52, 1, pp 85-95

<Go to ISI>://000226051800007 AND <http://www.botanischergarten.ch/Organic/Van-Bueren-Consequences-2004.pdf>

Van Bueren, E.T.L. & Struik, P.C. (2005)

Integrity and Rights of Plants: Ethical Notions in Organic Plant Breeding and Propagation. Journal of Agricultural & Environmental Ethics, 18, 5, pp 479-493

<Go to ISI>://000231949300003 AND <http://www.botanischergarten.ch/Organic/Van-Bueren-Ethical-2005.pdf>

Van Bueren, E.T.L., Struik, P.C., & Jacobsen, E. (2002)

Ecological Concepts in Organic Farming and Their Consequences for an Organic Crop Ideotype. Netherlands Journal of Agricultural Science, 50, 1, pp 1-26

<Go to ISI>://000181462100001 AND <http://www.botanischergarten.ch/Organic/Van-Bueren-Lammerts-ecological-concepts-2002.pdf>

Van Bueren, E.T.L., Struik, P.C., Tiemens-Hulscher, M., & Jacobsen, E. (2003)

Concepts of Intrinsic Value and Integrity of Plants in Organic Plant Breeding and Propagation. Crop Science, 43, 6, pp 1922-1929

<Go to ISI>://000186477700003 AND <http://www.botanischergarten.ch/Organic/Van-Bueren-Intrinsic-2003.pdf>

Verhoog, H., Matze, M., Van Bueren, E.L., & Baars, T. (2003)

The Role of the Concept of the Natural (Naturalness) in Organic Farming. *Journal of Agricultural & Environmental Ethics*, 16, 1, pp 29-49

<Go to ISI>://000180441900002 AND <http://www.botanischergarten.ch/Organic/Verhoog-Naturalness-2003.pdf>

Walker, B.H. (1992)

Biodiversity and Ecological Redundancy. *Conservation Biology*, 6, 1, pp 18-23

<Go to ISI>://A1992HM02900009 AND <http://www.botanischergarten.ch/Organic/Walker-biodiv-redundancy-1992.pdf>

Walker, B.H. & Langridge, J.L. (2002)

Measuring Functional Diversity in Plant Communities with Mixed Life Forms: A Problem of Hard and Soft Attributes. *Ecosystems*, 5, 6, pp 529-538

<Go to ISI>://000178121000002

Watson, C.A., Atkinson, D., Gosling, P., Jackson, L.R., & Rayns, F.W. (2002)

Managing Soil Fertility in Organic Farming Systems. *Soil Use and Management*, 18, s1 %R doi:10.1111/j.1475-2743.2002.tb00265.x, pp 239-247

<http://www.blackwell-synergy.com/doi/abs/10.1111/j.1475-2743.2002.tb00265.x> AND <http://www.botanischergarten.ch/Organic/Watson-Soil-2002.pdf>

Williams, N.M. & Baines, G. (1993).

Traditional Tecological Knowledge: Wisdom for Sustainable Development. pp Centre for Resource and Environmental Studies, Canberra, Australia.

Wilson, J.D., Morris, A.J., Arroyo, B.E., Clark, S.C., & Bradbury, R.B. (1999 link, WOS)

A Review of the Abundance and Diversity of Invertebrate and Plant Foods of Granivorous Birds in Northern Europe in Relation to Agricultural Change. *Agriculture Ecosystems & Environment*, 75, pp 13-30

Witcombe, J.R. (1999)

Does Plant Breeding Lead to a Loss of Genetic Diversity? *In Agrobiodiversity, Characterization, Utilization and Management* (eds D. Wood & J. Lenne), pp. 245-272. CABI Publishing, Oxon, UK and New York, NY, USA,

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>

Wood, D. & Lenne, J. (2006)

The Value of Agrobiodiversity in Marginal Agriculture: A Reply to Bardsley. *Land Use Policy*, 23, 4, pp 645-646

<Go to ISI>://000239322300026

WTO Doha Ministerial Declaration (2001),

Electronic Source: Ministerial Declaration (ed WTO),

http://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.pdf