Why farming with high tech methods should integrate elements of organic agriculture

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In the previous article [Ammann, K. (2008) Feature: integrated farming; why organic farmers should use transgenic crops. New Biotechnol. 25, 101–107], in a plea for the introduction of transgenic crops into organic and integrated farming, it was announced that the complementary topic, namely that high tech farmers should integrate elements of organic agriculture, will be a follow up. Some selected arguments for such a view are summarised here. Basically, they comprise a differentiated view on agro-biodiversity outside the field of production; landscape management methods to enhance biodiversity levels. Both elements are compatible with basic ideas of organic farming. First, Precision Farming is given as one example of the many ways to support agricultural production through high technology, with the aim of reducing energy input, maintaining excellent soil conditions and enhancing yield. It is clear from this analysis that modern agriculture and certain elements of organic–integrated agriculture are compatible. There are sectors of high tech farming, such as the introduction of a better recycling scheme and also a better focus on socio-economic aspects, which need to be taken up seriously from organic–integrated farming, a system which puts a lot of emphasis on those elements and for which important research data are available. In the final part a new concept of dynamic sustainability is presented.
Introduction
This text is a follow up to the previous publication in this journal ‘Integrated farming: why organic farmers should use transgenic crops’ [1]. In this first part, the main topics were: (a) principles of organic farming; (b) in basic processes, no difference exists between natural mutation and genetic engineering; (c) conventional crops have more transcriptomic disturbances than transgenic crops and (d) therefore there is no basic reason for organic farmers to not to use selected GM crops, as long as they fit into organic farming systems they can help to control pests and weeds in an ecological way and at the same time secure better yields and higher agricultural production. In a short outlook, it was also mentioned that agricultural biodiversity needs a subtle and balanced view and conventional agriculture should take up more ecological thoughts and strategies. Clearly, traditional knowledge is still an unknown reservoir of ecological wisdom, while social networking structures are also, in many cases of modern agriculture, a desideratum for many reasons.

The complementary text here was announced in the conclusions. This time we ask the question of whether farming with transgenic crops should adopt some of the organic/ecological production strategies. The answer will be similarly differentiated as in the previous article.

Concepts of farming with high technology methods: the example of Precision Farming
There are hundreds of ways to practise farming with high technology methods, just as there are innumerable ways to practise ecological and organic farming. It is not the aim of this article to give a complete overview of modern farming methods, but rather we concentrate here again on giving a comparison of farming with organic/ecological methods and farming with the use of high technology applications, including transgenic crops. Again the aim will be to reduce the contrasts, often exaggerated and driven by ideology on both sides. In the previous article, the concept of organic farming was described with the recently published principles of IFOAM (International Federation of Organic Agriculture Movements). In the case of mainstream agriculture this is not so easy, because literally hundreds of organisations have their own guidelines and constitutions. There is an extremely broad palette of opinions and views manifested in hundreds of papers. Therefore we resort again to an aspect of modern agriculture, which is still in stark contrast to organic farming – and again, the strict boundary in between is to be questioned.

Farming with high technology methods can be understood as Precision Farming (PF). As with all such expressions, it is a label for a strategy, here often with the meaning of satellite steered farming with geographical information systems or other (remote) sensing methods, combined with high tech sowing and harvesting machines. PF is not a single technology, but rather a suite of technologies that can be assembled into a system [2] including in most cases modern breeds of crops, transgenic traits produced by professional seed companies.

A boost in new breeding can be expected by the new breakthrough zinc-finger technology [3,4] which makes it possible to insert transgenes in higher plants at a precise locality. This was possible formerly under the label of ‘gene targeting’, but under much lower, less manageable frequency [5,6].

Farmers are expected in the near future to adopt various component technologies, depending on their needs and other site-specific characteristics of the business.

PF is a set of farming methods, introduced primarily in the naturally treeless regions (previously covered by prairie vegetation) and rich soils of North America, and ideal for industrial farming with heavy machines and high production levels, but nowadays rapidly spreading all over the world in countries with good infrastructure resources in agriculture.

PF can also be used for remote control in relatively small structured agriculture, for instance for improved crop discrimination in India (Hyderabad), where it was possible to distinguish by satellite remote sensing (Resourcesat-1) [7] between ca. a dozen crops/cultivation types. Many research papers demonstrate nicely, with colourful illustrations, that satellite mapping is en vogue and will deliver ultra-exact imaging in the future. However, the activity still concentrates on research, and the applications do not yet reach a broad range as GM crops do per se [8].

PF has also been evaluated to assess important soil parameters, such as organic matter (OM), in real-time mode [9]. In regard to calibration, Christy compares two predictions of OM with field data yielding high correlation ($R^2 >= 0.95$). Such high $R^2$ figures are not unusual in multivariate calibration, as has been shown for instance with biomonitoring air pollution with a set of 40 species of epiphytic lichens [10–12].

Remote sensing in combination with intelligent statistical data analysis can facilitate the important step in the evolution from uniform field management to site-specific management. Provided researchers and producers work closely together, it will soon be possible to come to practicable site-specific management [13]. In a ten-step protocol including cleaning-up, trimming and transforming the data, Taylor et al. describe the decision making process to conclude for the optimal number of management classes: two classes in the case study. With the help of this information, farmers can make decisions regarding optimal fertiliser management, given that class A has much lower yield potential in a low-average rainfall year but might respond well to late-season fertiliser when within season rainfall is high. The two classes should as a consequence not be managed uniformly, see Fig. 1. However, the authors see the necessity of further expert input in the decision-making process, and potential for further methodological developments as confirmed recently by the same Australian research group [14].

A recent review [15] comes to conclusions with an integrative spirit, namely that the use of computers and sensors for real-time decisions is growing rapidly, but the real value of the technology can only be translated to optimal agricultural management if those data are integrated with agronomic knowledge and experience. The same cautious picture is obtained by Lamb et al. [16], calling for a more distanced view in innovation, because very few technologies associated with PB have reached the end of the hype cycle (Fig. 2), which the author takes as a normal phenomenon in innovative agricultural development. This holds true not only for PF, but also for other technologies like genetic engineering (or gene splicing), for which we are undoubtedly on the slope of enlightenment (typically enough opposed by conservative individuals who question even historic enlightenment today), and in a few cases of major GM crops we are in the plateau of successful productivity [8].
PF is of growing importance in automatic weed recognition, and several papers have been published over the years, some remarkably early, thus documenting some of the five key stages of Fig. 2 properly [18–23]. The most recent review [24] demonstrates progress in science and practice. There are cases reviewed of automatic weed control [25] combined with robotic weeding. Several prerequisites are necessary for a functioning robotic weed control system. (i) Machine vision-based automatic row guidance in real time (accuracy a few centimetres!), also able to work in sown (not planted) field rows, with a capacity of weeding densities up to 200 weeds/m²; and ability to work with missing plants in the row (in organic fields where emergence is about 70%, conventional fields usually with an emergence of 90%). The vision system must be adaptable to local and regional conditions in soil and climate. (ii) Also essential is the ability of the vision system to recognise plant species on the basis of their biological morphology (Fig. 3). But PF is not always done with remote sensing methods. Recently a comparison with two prototype soil strength profile sensors has been worked out with promising results [26]. And also when it comes to mapping yield more precisely, remote sensing methods are well established [27–31].

There is also a new trend in ecological and organic agriculture for PF, although often with a less technological touch, strongly emphasising local knowledge built on social networks and integrated decision-making systems. Electronics still plays a minor role and remote sensing via satellite imaging is – to the best knowledge of the author – still absent from the peer reviewed literature – although [13] is considering such tools. This paper still remains a rare example of organic precision agriculture, proposing ‘down to earth’ electronic sensors that respond strongly to clay content and soil moisture in non-saline soils to determine important parameters for the management system. Coupling the information from ECa sensors with other crop sensors, such as yield monitors and crop imagery, has been promoted [13] as a concept of management classes among Australian grain producers. Another rare Internet finding is a conference paper [32] outlining the future use of remote sensing and PF methods in organic farming. The aim of this study was to assess the effects of a GPS-controlled precision tillage system using permanent tracks on soil structure, nutrient use efficiency and spinach yield. The study was carried out at an organically managed arable farm in the Netherlands.

**Elements of organic/ecological farming which could be adopted by farmers using modern agricultural technology**

As was elaborated in the first part of this article [1] and its preceding text in the Handbook of IP methods [33], there exist controversial views about biodiversity in general and in agriculture in particular. This topic has also been covered more broadly for biodiversity as a whole by the author [34,35], here we concentrate on the case of agro-biodiversity. Biodiversity within the production field cannot be the solution, although the results of the British Farm Scale Experiments suggest that this is basically a good thing. Yet there are reasons of doubt: because some weeds provide toxic substances to the harvest, an old problem in agriculture, it cannot therefore be the goal of such experiments to enhance biodiversity within production fields. For more extensive crucial comments about the British experiments, see [36,37] – these experiments are actually asking the wrong questions.

**The case of agro-biodiversity, new insights**

In many publications about agro-biodiversity, it is hardly questioned whether biodiversity per se is a good thing. It is just assumed that we need to strive for as much biodiversity as possible, sometimes at the cost of simple production rules. This is why the following subchapters will try to produce a fresh and more pragmatic look at biodiversity in agriculture.

**Nature’s fields: ancient wild crop relatives often grew in monodominant stands**

Species and genetic diversity within any agricultural field will inevitably be more limited than in a natural or semi-natural ecosystem. Surprisingly enough, many of the crops growing in farming systems all over the world have traits of ancestral parents,
which lived originally in natural monocultures [38]. This is, after all, most probably the reason why our ancestral farmers chose those major crops. There are many examples of natural monocultures, such as the classic stands of Kelp, Macrocystis pyrifera, already analysed by Darwin [39] and, more relevant to agriculture, it has now been recognised by agro-ecologists that simple, monodominant vegetation exists throughout nature in a wide variety of circumstances. Indeed, [40] reporting [41,42] use the term ‘natural monocultures’ in analogy with crops. Such monodominant stands might be extensive. As one example out of many, Harlan recorded that for the blue grama grass (Bouteloua gracilis): ‘stands are often continuous and cover many thousands of square kilometres of the high plains of central USA.’ It is of utmost importance for the sustainability of agriculture to determine how these extensive, monodominant and natural grassland communities persist and when and if we might expect their collapse.

More examples are given in Wood and Lenne [43]; here we cite a few more cases. Wild species: Picea abies, Spartina townsendii, Pieridium aquilinum, various species of Bamboo, Arundinaria ssp. [44]. Also the related Phragmites communis grows in large monodominant stands, which contain large clones. They renew after some decades over seeds (just like the large tropical Bamboos do in amazingly regular periods), which causes temporary local breakdowns of the populations. Still other ancestral cultivars are cited extensively [38]. Sorghum, the wild variety verticilliflorum, is the most widely distributed feral complex of the genus, with a broad climatic plasticity, extending almost continuously east of 20° east longitude from the South African coast to 10° north latitude. It overlaps along its northern and northwestern borders with var. aethiopicum and var. arundinaceum, again hybridising extensively. It grows over extensive areas of tall grass savannah in the Sudan [38]. Typically enough, [45] found a remarkably narrow genetic basis for the variety verticilli-florum in their analysis. Wild rice: Oryza coarctata is reported in Bengal as growing in simple, oligodiverse pioneer stands of temporarily flooded riverbanks [46]; Harlan ascribed Oryza [47] to monodominant populations and illustrated harvests from dense stands of wild rice in Africa (Oryza barthii, the progenitor of the African cultivated rice, Oryza glaberrima). O. barthii was harvested wild on a massive scale and was a local staple crop across Africa from the southern Sudan to the Atlantic. Grain yields of wild rice stands in Africa and Asia could exceed 0.6 tonnes/ha – an indication of the stand density of wild rice [48].

Botanists and plant collectors have repeatedly and emphatically noted the existence of dense stands of wild relatives of wheat [38]. For example, in the Near East, massive stands of wild wheats cover many square kilometres [49]. Wild einkorn (Triticum monococcum
subsp. boeoticum) in particular tends to form dense stands and, when harvested, its yields per square meter often match those of cultivated wheat under traditional management [50]. Wild Ein-korn occurs in massive stands as high as 2000 m altitude in southeastern Turkey and Iran [51]. Wild emmer (Triticum turgidum subsp. dicoccoides) grows in massive stands in the northeast of Israel, as an annual component of the steppe-like herbaceous vegetation and in the deciduous oak park forest belt of the Near East [52]. Wild wheat was also recorded to grow in Turkey and Syria in natural, rather pure stands with a density of 300 m\(^{-2}\) [53].

**Agro-biodiversity and food webs of insects**

In a recent notable paper Macfadyen et al. [54], were able to show in extensive field studies, focusing on the food web and its ecosystem services, instead of using traditional biodiversity descriptors, that things are a bit more complex than expected. Although organic farms support greater levels of biodiversity on all three trophic levels, as shown in meta-studies [55,56], these systems provide greater levels of natural pest control and therefore also greater resistance towards the invasion of alien herbivores, because more parasitoids attack herbivores. However they also predict [54], as a consequence of higher species richness, a lower connectance and therefore a lower robustness of organic farms to species loss [57].

**Extreme population dynamics of agricultural systems**

It is amazing to see that there are entomologists who wonder about the slightest detail in insect population shifts and foodwebs to satisfy their effort to find negative effects of transgenic crops on non-target insects, and in so doing often forget some basics about experimentation. This has recently happened again with a paper from lab entomologists [58], which has been refuted justifiably on multiple grounds by an important consortium [59]. Here only one important reason is mentioned: feeding experiments have been done in the past [60,61] with low quality prey, but when healthy preys are used, the lacewings have proven extremely high tolerance to a variety of tested crops [62,63]. Given here as a typical controversy on experimental details, some of the main influences are completely forgotten: just imagine the mass extinction effects which happen with certitude, if you change the cropping system, often from year to year. Interestingly enough, there is literature on the detrimental effects of crop rotation against pest insects [64], but it is difficult to find fieldwork data on non-target insects.

Agricultural ecosystems can be dynamic in terms of species diversity over time as a result of management practices. This is often not understood by ecologists who involve themselves in biosafety issues related to transgenics. They still think in ecosystem categories close (or seemingly close) to nature. Biodiversity in agricultural settings can be considered to be important at a country and local level in areas where the proportion of land allocated to agriculture is high: see Ammann in [65]. This is the case in continental Europe for example, where 45% of the land is dedicated to arable and permanent crops or permanent pasture. In the UK, this figure is even higher, at 70%. Consequently, biodiversity has been heavily influenced by human for centuries, and changes in agrobiological management will influence biodiversity in such countries overall. Innovative thinking about how to enhance biodiversity in general, coupled with bold action, is crucial in dealing with the loss of biodiversity.

**Centres of crop biodiversity**

Centres of biodiversity are a controversial matter, and even the definition of centres of crop biodiversity is still debated. Harlan [66] proposed a theory that agriculture originated independently in three different areas and that in each case there was a system composed of a centre of origin and a noncentre, in which activities of domestication were dispersed over a span of 5–10,000 km. One system was in the Near East (the Fertile Crescent) with a noncentre in Africa; another centre is north Chinese and a noncentre in S.E. Asia and the south Pacific, with the third system including a Central American centre and a South American noncentre. He suggests that the centres and the noncentres interacted with each other.

There is a widespread view that centres of crop origin should not be touched by modern breeding because the biodiversity treasures are so fragile that these centres should stay free of modern breeding—rather like museums. It is an error to assume that regions of high biodiversity are particularly susceptible to invasive processes. On the contrary, there are studies showing that high biodiversity means more stability against invasive species, as well as against genetic introgression [67–69] and most recently by [54] commented on above. The introduction of new predators and pathogens has caused well-documented extinctions of long-term resident species, particularly in spatially restricted environments such as islands and lakes. One of the (infamous cases of extinction of an endemic rare moth is documented from Hawaii; it was caused by a failed attempt at biological control [70,71]. However, there are surprisingly few instances of extinction of resident species that can be attributed to competition from new species. This suggests either that competition-driven extinctions take longer to occur than those caused by predation or that biological invasions are much more likely to be threaten species through inter-trophic than through intra-trophic interactions [72]. This also fits well with agricultural experience, which builds on much faster ecological processes.

**Selected proposals for improving high technology agriculture related to biodiversity**

**Biodiversity and agricultural landscapes**

High potential to enhance biodiversity considerably can be seen at the level of regional landscapes [73,74], and with the help of remote sensing methods it should be possible to plan for much better biodiversity management in agriculture [75]. This is also a good point for organic farming in marginal regions, such as the Norwegian Sognefjord. An analysis has shown the positive influence of small-scale organic farming in this region [76]. Some of the more important papers demonstrate the intensive research activities on the relationship between landscapes and biodiversity [76–87]. A bibliography, containing a total of more than 300 papers dealing with the impact of ecological agriculture on landscapes and vice versa can be found in [88]. There is a great deal of potential in restructuring landscape in regions with a high yielding industrial agricultural production. In a thoughtful multivariate scheme Benton et al. [89] show the highly complex interactions between farmland activities and the diversity of bird species.

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

**More biodiversity through mixed cropping**

Mixed cropping systems have been proposed for a variety of agricultural management systems. The bibliography coming from Web of Science reaches nearly 300 items and many papers offer a wide variety of options. There is no reason why modern cropping system with industrial automatiation could not cope with some specific mixed cropping systems. Mixed cropping offers advantages in pest management and soil fertility [90–92], but is also subject to limitations, such as the fight against the maize stem borer [93], yet under low pest pressure a system of maize-bean intercropping in Ethiopia seems to be successful [94].

**Varietal mixture of genes and seeds**

Also on a microscale of seed production, biodiversity could play a new role. Precision Biotechnology could also mean a combination of resistance genes, achieved either through gene stacking [95–97] or by taking up the idea of artificial gene clusters [98]. This has been the accepted strategy up to now. But this goal of introducing more biodiversity in the fields could be achieved in a much simpler way. Other than complex gene stacking, it would be easier to create a seed mix in which each seed contains a single resistance and the appropriate mixture could be adapted to the local pest situation. This would considerably lower selection pressure [99] and would create a situation, which comes closer to nature, where we encounter many genomes within a square mile and dozens of different resistance genes. Varietal mixtures have been proposed by several authors [100–103].

**More biodiversity in the food web including non-target insects by reducing pesticide use with transgenic crops**

If we refrain from heavy pesticide use, beneficial insects will come back – as they do in Bt maize fields, [104–107] and adapt to GMOs. Much has been written on agricultural biodiversity; foremost the book of Wood and Lenne [43] should be mentioned here, a refreshing mix of modern agriculture and independent views on biodiversity. Each chapter, written by some of the best experts in the field, deserves to be taken up in the future debate on agriculture and biodiversity. The chapter on traditional management written by [108] provides a very enlightening summary. Of course those management details have to be carefully selected for modern agriculture and where necessary also to be adapted. As a catalogue of ideas the tables in this article serve well.

There are also comparative data available on long-term development, with organic and conventional agriculture. The results show positive trends towards more biodiversity, when conventional farms are converted into organic farms, but the influence of local management habits and also a changing landscape are very important [109] and high technology farming could again learn.

**On the wish list: more crop biodiversity**

Another important aspect has been covered by the recently published book of Gressel [110] with an interesting theme: a proactive review on orphan crops, their present day deficiencies (the ‘glass ceiling’) and how biotechnology methods could greatly enhance them, so that they could be commercialised in future. It is especially fascinating to see how the author blends modern molecular biology with a deep insight into agriculture and its forgotten crops. This is an important boundary line, where organic/ecological farming can meet and create considerable synergy. Even within crops with a seemingly low reputation, like the herbicide tolerant soybeans, trends regarding diversity are positive, because a report from Iowa shows [111]: recently there are more than 700 nematode resistant soybean traits registered, the majority of them herbicide tolerant.

**Plant breeding revisited**

Plant breeding has gone through dynamic developments, from marker assisted breeding to transgenesis, with steadily improved methods up to the latest development of the zinc-finger enzyme assisted targeted insertion of transgenes in complex organisms [3,4]. The development is so rapid that it is necessary here to make some additional remarks related to the paragraph in the first of the articles dealing with the topic of organotransgenesis [1]; according to the descriptions of the new technology, it will be even more difficult for breeders of new organic crops to refuse zinc-finger transgenesis, because it is very likely to be that the transscriptomic disturbances will be even smaller in future – compared to the clumsy and tedious methods of conventional breeding. This does not mean that there is no value in the development of conventional breeding methodologies for organic crops. It is obvious that high technology breeding of new crops can also learn from the newly developed organic breeding strategies.

In a recent and comprehensive paper, a consortium lead by Wolfe et al. [112] gives an account of breeding crops for organic farming. Many of the characteristics required in new varieties are common to both conventional and organic agriculture, but there are also a number, mostly of complex nature, that must have a higher priority in organic farming. Characters that are important for the farming system and crop rotation, weed competition and adaptation to arbuscular mycorrhizas have a higher priority. To rationalise the long enduring selection process, it is necessary to focus on simultaneous selection processes such as weed competition, nutrient uptake and disease/pest resistance. It seems that the trend to ban any kind of in vitro breeding technology is unfortunately growing and therefore anticipated, including marker assisted breeding, which will deprive the organic community from modern and very efficient tools with which to achieve the genomic breeding goals. This way, the slowdown process cannot be stopped and the difficulties will grow with the need to cope with a considerably higher diversity of environmental factors, which does not favour centralised breeding. The real force of breeding for organic crops comes from the strong link to social structures, as promoted by a variety of breeding programmes, such as those on Sorghum in Western Africa by researchers from Wageningen [113], explicitly enforcing participative working strategies including traditional knowledge. These thoughts and strategies could well also be taken up by breeding programmes using unrestrained all modern DNA related manipulation methods.

**Final remarks on the improvement list related to biodiversity**

This cannot be the place to give a comprehensive list of possible improvements, which are compatible with high technology agriculture, which would fill dozens of pages and could also well be the
intellectual engine for a long-term research programme. Rather, the reader is referred to some books written to improve agricultural biodiversity – most of the chapters cited below do not envisage improving high technology agriculture per se, indeed most of the authors see themselves in opposition to it. In the eyes of the author this is at least questionable and it would be much more fruitful to find opportunities for collaboration and creation of synergy.

There are several books and reports, as well as numerous peer reviewed journal articles, dealing with all aspects of ecological agriculture. The authors provide proposals on how to enhance sustainability, how to preserve biodiversity and what can be done so that traditional knowledge with all its treasures does not vanish. There are a majority of authors who really do not lose the focus of the developing world and its dramatic problems, but they avoid topics like modern breeding among others [114–117]. Scherr and McNeely [116] and in particular also Wood and Lenne [43] offer highly interesting chapters on the science and practice of eco-agriculture. It is impressive for the reader to learn about various schemes of integrated farming systems, and some are really integrative and especially strong on the side of analysing social dynamics, history and economy, topics sometimes forgotten by conservationists and certainly by proponents of high technology agriculture. By contrast, it is striking to see, with a few notable exceptions, that modern breeding technology and in most cases also high technology management methods like remote sensing, GIS supported systems are often only briefly mentioned. By contrast, it is rewarding to see in the same book a treatment on remote sensing [32], stating that this is an important instrument in the landscape planning of eco-agriculture (GIS-based decision support). Nevertheless, the scarcity of such treatments provokes the serious question about bias against modern agricultural technology. The same can be said of the IAASTD report. In a rebuttal to a letter to Science [118] attacking the views of Fedoroff [119], the author [120] commented about the IASDD report [121]:

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

The good thing about all those publications on eco-agriculture is to see with an open mind that transgenic crops and all high technology practices, even the first generation transgenic crops, could very well fit into eco-agriculture and, vice versa, that eco-agricultural strategies could very well be introduced into high tech agriculture. The possible positive role of biotechnology related to ecology and conservation was stated as early as 1996 [122]. It is a fact which has been repetitiously stated with solid justification: present day commercialised transgenic crops are not inherently scale dependent, which means they can, with some adaptation in management, very well be integrated into small-scale farming – which has been shown with success in India and China with Bt cotton [123–125].

As summary and synthesis of both features on organotransgenics in New Biotechnology, a statement of sustainability is presented. It is, as one can infer from both texts, not written in a defensive way. On the contrary, the view is clear: we can only achieve the goals of sustainability successfully if we are ready for progress, changing the world and the course of evolution, thus producing the best outcome for biodiversity, humanity and our planet.

**Final remarks about sustainability**

An intelligent scheme of sustainability (among others [126]) has been coined by Mendel Biotechnology, combining elements of social/environment to ‘Bearable’, social/economic to ‘Equitable’ and economic/environment to ‘Viable’, and where all three elements of social/environment/economic overlap, sustainability resides ([http://www.mendelbio.com/sustainability/index.php](http://www.mendelbio.com/sustainability/index.php)). A convincing way forward for the understanding and the practice of agricultural sustainability is described by Nash _et al._ [127]. Using the notation and software tools for the Unified Modeling Language (UML), a complete model of all identified data-flows was created. Individual data-streams relating to particular source or product datasets were then extracted from this model. These data-streams present a practical application of the model in identifying the benefit that might be obtained from a particular gathered dataset (e.g. yield data) or in identifying the data that must be gathered to generate a particular product dataset (e.g. sustainability indicators).

For some years, the author has tested in debates of numerous events a sustainability scheme, which is somehow similar to the one by Mendel Biotechnology. It concentrates more on the essential activities of humanity with the goal to solve the urgent global problems on how to feed the ever-growing number of hungry people.

If we want to aim at a more sustainable world, it needs more than defensive measures usually advocated. Sustainable development has been defined in many ways, but the most frequently quoted definition is from _Our Common Future_, also known as the Brundtland Report [128]:

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

- the concept of needs, in particular the essential needs of the world’s poor, to which overriding priority should be given and
- the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs.

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

The declaration of the OECD, authored by Yokoi [129], catalogues a range of concrete measures and rules to achieve a more
The scheme in Fig. 4 meets those needs and asks for an intransigent view of the future. The three-column model has been chosen with care, and as one can see:

- **The most important column to the left is agriculture.** It demands ‘to foster renewable resources, knowledge based agriculture’ [130] and with some additions [131–133]. The rather provocative phrase Organic Precision Biotechnology Agriculture is now coined; a shorter one might be ‘Organotransgenic’ Agriculture, but the most elegant term ‘Organic’ [134] is unfortunately already lost to other purposes. By no means does this mean to suggest that the mistakes of organic farming or exaggerated industrialisation of production should be included; those mistakes in organic farming are dealt with fully in my previous article in New Biotechnology [133]. The most dramatic mistakes in organic farming are the low yield, documented in many long term monitoring experiments and the eco-imperialist attitude towards farmers of the developing world [135–138,167,168]. On the positive side is some pioneering work in developing recycling loops in agriculture [139–145] and also in better landscape management [76–87,146–149]. (For further documentation, see the previous paragraph on landscape management and organic farming.) To balance local production against global trade will not be easy, because the equilibrium between the demands and perils of pressure to produce for global trading and local food production must be found. The economic basis should be important, but local social networking and life need to be taken into account as well.

- **Middle column: socio-ethics:** It is of utmost importance to reach greater equity, especially in these difficult times of the credit crunch 2009. It will be imperative to reduce the huge agricultural subsidies paid to the farmers in the developed world, a kind of protectionism that needs to be questioned. Access to global markets is important, but should not hamper local food production and social structures in the developing world. The myth that developing countries are in the tight grip of multinationals can be debunked with some publications [150–156]. A new creative capitalism – a novel discussion which would have been totally utopic before the global economic crisis – needs our attention. It will be a demanding process to reconcile traditional knowledge with modern science; the intellectual property (IP) system is up to now completely unilateral, and no wonder because it has been created by the developed world. In the IP handbook of Krattiger et al. (accessible over the Internet), there are numerous contributions offering innovative solutions to reconcile this contrast; the author also contributed and offered some solutions [33]. This contribution made it clear that we need not only a big boost in breeding science, but also a new focus on emerging fields in science: biomimetics (formerly bionics) could be a promising area of research, where high technology equipment is certainly helpful, but not indispensable, and agriculture needs new research goals for new production lines. Hygroscopic mechanisms are offered within the plant kingdom and also abundantly with insects, but the details, often functioning for 200 years beyond the organismal death, need clarification; maybe in some future days we will be able to use the adiabatic moisture differences of our daily climate fluctuations to produce power.

- **Right column on evolution:** The most audacious third column questions our view of evolution in both the biological and the general sense of the word. Evolution deplorably still contains – often not consciously – some elements of creationism [157] – and this not only with opponents of gene splicing. It will be important to emancipate these views and make clear that for many years we have taken human evolution into our own hands through modern medicine, and we need to deal with the problems and prospects of a new evolutionary view. Modern breeding has the potential to enlighten the population, if done in an ethically acceptable way and if communicated properly. The tasks will grow over the coming decades and in many fields of science we are already now heavily dependent on calculation power; therefore, let us make sure that mathematical algorithms can be translated into useful artificial intelligence in the service of mankind. We need the help of all new and emerging technologies (of course regulated in a sensible way) to enhance food production and the livelihood of mankind. The statement ‘only one planet’ is at the same time a reminder to precaution, but appeals also to our responsibility to take evolution as a whole into our own hands. This can only be achieved if we have a close and conscious look at the cultural side of human evolution as a whole with all its consequences for ourselves. This will be another string of thoughts in a next feature on ‘Darwin and beyond’, the development of the evolutionary theory after Darwin on all levels, from the molecules to culture; it will need historical and philosophical scrutiny, going far beyond the usual disputes on technologies [158,159].

**Some closing words:** Agriculture is at the centre of this text, and rightly so, since we have the urgent task of feeding a billion hungry people, and there is no time for sterile sophisticated bickering on whether some hypothetical negative effects could emerge decades from now, because by then hundreds of millions of people would have died of hunger and disease. The case of the golden rice is symbolic for the situation of mankind: we can develop it as fast as we can, unhampered by over-regulation – or we might tolerate
hundreds of thousands of children dying every year from pro-vitamin A deficiency. It is no coincidence that this article closes with some references essential for the Golden Rice debate [160–166]. Actually the solution would be extremely simple and its unconditional support would honour all institutions of the United Nations, including the Convention of Biodiversity that has created the Cartagena Protocol on Biosafety. Human beings should be part of any risk assessment in technology: this is a request with enormous ethical implications.

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