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Fundamentals of agricultural sustainability or the quest for the Golden Fleece

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Abstract

In this paper, different aspects of development sustainability will be highlighted by stressing the fact that even the smartest drivers are necessarily characterized by the continuous uncertainty we all must live with. Different development drivers will be illustrated in the field of agriculture, nature and environment, all attempting to weigh the contradicting, even conflicting parameters of life and decay. Agricultural sustainability drivers will encompass human, cultural, social and political aspects together with components of metabolism, genetics, energy, environment and farm management. It will be concluded that each sustainability approach should be precisely documented using exact parameters and not unproven social or emotional attributes. Quantitative cost to benefit ratios will be proposed as sustainability indicators. In short, sustainability is an ideal state in the area of conflict between environmental change, evolution of life and thermodynamic laws. It cannot be defined as a stable state, but as a state of relative stability during a certain but limited period of time. Sustainability strongly depends on a reliable energy resource that, in thermodynamic terms, enables the preservation of order in an open (eco-) system at the expense of the order of the environment.

1. Semantic definitions and anthropomorphic derivatives of sustainability

In recent years, the term *sustainability* has become a mythological definition of endlessly revolving processes where all components are deemed renewable as if it were a *"perpetuum mobile"* i.e. the quest for the unattainable Golden Fleece. Sustainability is generously used in a large spectrum of events, without understanding its actual meaning. This lack of definition allows an overuse of sustainability qualifications, which nobody understands, believes, nor refutes. It adorns a majority of research and development projects as proof of unrivalled quality, which is swiftly considered as a vital compliance to the ultimate development prerequisite for which all zealous stakeholders and administrators are likely to agree, or better said, likely to find enough security for their personal insecurity.

Resilience is the companion concept that acknowledges the invariant model status of virgin nature. In fact, this is a gimmick. Most geological, geomorphological and climatic changes are unique and irreversible, and hence, they will prevent any resilience process to recover the original status, albeit well-meant. A case in point is the very recent geomorphological processes (quaternary) that have changed the face of the African continent in an irreversible way: the Ubangi-Shari [Oubangui-Chari in French] disruption inducing the reduction of the Lake Chad watershed basin and contributing to the expansion of the great Sahara desert and, concomitantly the reduction of the original vegetation. "In the 1960s, a plan was proposed to divert waters from the Ubangi to the Chari River which empties into Lake Chad. According to the plan, the water from the Ubangi would revitalize that lake and provide livelihood in fishing and enhanced agriculture to tens of millions of central Africans and Sahelians" (Wikipedia 2013a). And yet, we still observe some remnants of this earlier lush period at the edge of the Sahara desert in the form of "paleovalleys" which can come alive all of sudden for a few months and then disappear. North and South of this enormous space we still encounter occasional lotifagous people eating the same nymphea spp. as their ancestors used to (Figure 1). "The submerged leaves, the starchy, horizontal creeping rhizomes, and the protein-rich seeds of the larger species have been used as food by humans throughout history" (Encyclopedia Brittanica 2012).

Figure 1: Nymphea or Nympheoid aquatic plants are still collected along the Komadugu river between Niger and Nigeria *(Source: Marc Janssens)*

The term *sustainability* was coined by the Brundtland report of the "World Commission on Environment and Development" of the United Nations: "*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" United Nations General Assembly (1987). Thereafter, sustainability was defined as a principle for resource management in Agenda 21 (Rio de Janeiro 1992). "Sustainable Development" underpinned the eight Millennium Development Goals (MDG) which have strongly influenced development cooperation since 2000. At the 2005 World Summit on Social Development it was noted that it requires the reconciliation of present needs with the needs of the environmental, social equity and economic demands - the "three pillars" of sustainability (or the 3 Es) (UN 2005). These ideas were adopted by the European Report on Development 2012 (European Union 2012) and by the final document of UN-conference 2012 (Rio+20). All participating countries agreed to formulate common goals for "Sustainable Development". The idea is to work out rules and guidelines for Sustainable Development Goals (SDG) with targets and indicators, which shall be implemented by 2015 and shall have validity for all Industrialized and Developing Countries and not only Developing countries as with the MDG. This means validity for all sectors in the economy (Wagner and Wellmer 2009).

Some derivatives of "sustainability"

We all dream of an eternal (sustainable) and happy life, whatever *religion, philosophy* or *humanist school* we belong to. At the core of most religions or schools of wisdom, the message is to free oneself from all temptations or evil actions diverting us from being good and charitable with our family and fellow citizens. If so, eternal (sustainable) happiness will be bestowed upon you. The medieval scholastic preacher, Meister Eckhart used to say: "When I preach, I usually speak of detachment and say that a man should be empty of self and all things; and secondly, that he should be reconstructed in the simple good that God is; and thirdly, that he should consider the great aristocracy, which God has set up in the soul, such that by means of it man may wonderfully attain to God; and fourthly, of the purity of the divine nature". If the soul shall see with the right eye into eternity, then the left eye must close itself and refrain from working, and be as though it were dead (Wikipedia 2013b) .

In social and psychological sciences the question remains, how to educate children so that they achieve a successful, i.e. eternal (sustainable) and happy, life until death? How can they be rendered to believe in good actions, in working hard, in behaving under freely accepted moral rules? It is understood that a harmonious person will be respectful of the achievements of other persons and will perform much better because s/he concentrates her/his energy for the best instead of losing energy through entropy by either self-destructive or idle, if not evil, behaviour. The same is true at the community level, where a positive environment will concentrate energy for the overall wellbeing of a family, a community or a country at minimal energy cost. And last but not least, how can a family's or people's traditions and values be transferred to the next generation?.

Sustainability in a general sense is the capacity to support, maintain or endure. The attractiveness behind the ideal of sustainability in public and scientific discussion is difficult to explain, but may in some way be related to the all too human experience that everything is coming to an end, whether it be holidays, human life, life on Earth in general or even the Universe – although, with respect to the latter, hope still remains. Realizing the impossibility of maintaining a *status quo* until the end of days, it is not surprising that, from a more practical point of view, sustainability is considered achieved when a system is stable for a limited period of time – the reference here frequently being human generations: "We should hand over the Earth to our children the way we received it from our parents". In this context, it becomes unimportant that once upon a time on the place where we grow our wine, an ocean existed as indicated by fossil shells. It is regarded sustainable, when a grandson is still able to cultivate good-quality wine on the vineyard that a grandfather designed.

In natural sciences there are opposing views depending on the particular science. Geologists and astronomers will easily accept the fact that most natural phenomena are unique and time-specific, when considering large time scales. Nobody would dare argue that dinosaurs, mammoths or the Jurassic period are likely to revive. Resilience is not a subject of consideration. On the contrary, bio-sciences are tending towards equating sustainability as a naturally recurrent phenomenon insofar as no human hand will disturb its resilient return to a so-called pristine, virgin status called "eco-climax" or even "repository".

When dealing with *agricultural sustainability* it is clear that we should drop all possible anthropomorphic wishful thinking. "*Sustainable agriculture* is the act of farming using principles of ecology, the study of relationships between organisms and their environment" (Gordon McClymont, 2002 in: Wikipedia 2013c). Gordon McClymont also defined sustainable agriculture as "an integrated system of plant and animal production practices having a site-specific application that will last over the long term:

- Satisfy human food and fibre needs;
- Enhance environmental quality and the natural resources on which the agricultural economy depends;
- Make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- Sustain the economic viability of farm operations;
- Enhance the quality of life for farmers and society as a whole".

Raviv (2010) attempted to define sustainability in the field of organic horticulture. He underlined the difficulty of quantifying sustainability and pointed to the usefulness of the recently developed energy analysis for measuring both environmental services and material from production services.

It is feared that the world's population is about to exceed the carrying capacity determined by present agricultural potential. This means that current agricultural technology does not permit further demographic growth worldwide. Also with respect to economic growth, in 1972, the Club of Rome (1972) advocated *zero-growth*. "It predicted that economic growth could not continue indefinitely because of the limited availability of natural resources, particularly oil".

The present article deals with the fundamental and economic drivers of sustainability. It attempts to discard anthropomorphic interpretations or the abuse of terms like 'sustainability' or 'resilience' in agricultural development by suggesting indicators of "dynamic sustainability" implying buffering, adaptive and energy/resource saving strategies (Annex 1). An upcoming article (Janssens et al. 2014) will attempt to outline the integration of complex agricultural and environmental drivers of sustainability across generations.

2. Sustainability and metabolism

If we critically consider the aspects of life on Earth in the context of sustainability, isn't it a fact that the only stable (sustainable) aspect of life is change? And, more importantly, what would evolution be without change (to the environmental conditions)?.

The ancestral biosynthesis: Considering the development of life on Earth, there is evidence that the Wood–Ljungdahl pathway is the phylogenetically oldest pathway for assimilation of CO_2. It already existed a billion years before the first formation of oxygen (Ragsdale, 2004). Nowadays, it is still used by some strictly anaerobic bacteria and archaea. This pathway enables the use of elemental hydrogen (H_2) as an electron donor and CO_2 as an electron acceptor as well as a building block for biosynthesis. Moreover, it combines CO_2 assimilation into acetyl-CoA with the production of ATP via an energized cell membrane (Poehlein et al., 2012). Hence, during the very early stage of development of life on Earth, resources in the Earth's primeval ocean were consumed by chemosynthesis, for instance those available at hydrothermal vents (black smokers). Comparable ecosystems still exist today and have therefore been sustainable for more than 4 billion years. With the development of photosynthesis, a new resource of energy was made accessible for life, sunlight, allowing the use of an almost inexhaustible energy source.

The Great Oxygenation Event through Photosynthesis: The production of oxygen by photosynthesis resulted in the Great Oxygenation Event (GOE) around 2.4 billion years ago that wiped out a huge portion of the Earth's anaerobic inhabitants at that time. The production of oxygen, which is toxic to anaerobic organisms, was responsible for what was likely the largest extinction event in Earth's history and possibly also for the following ice age (snowball Earth). Hence, the cause of the GOE is a good example that sustainable strategies may end in disaster for ecosystems. Still, it was undoubtedly in this period of time when the evolution of the antioxidative system, protecting cells from reactive oxygen species and of oxidative signalling, was boosted.

Sustainability and longevity: During the first period of their life all organisms grow, hence anabolic processes dominate catabolic ones. Later, organisms reach some kind of steady state, where anabolic and catabolic processes are balanced, at the end, at least in some organisms, catabolic processes dominate – the organisms are dying. Nevertheless, other organisms such as bacteria, *Hydra sp*. and *Turritopsis nutricula* are potentially biologically immortal, although they are also susceptible to predation or disease. The longevity of these species depends either on the ability to balance anabolic and catabolic processes long-term (and to survive stressful situations) or to undergo a kind of rejuvenation process.

Disturbance of sustainable climax vegetation by evolution: In ecosystems, growth comparable to that of individuals can be identified, resulting in a so-called climax vegetation. Climax vegetations, such as forests, tundras, savannahs, grassland etc., are vegetations that establish themselves on a given site for given climatic conditions in the absence of major disturbance over a long time. They represent the quasi-equilibrium state of a given local ecosystem, where the biomass remains almost constant. The sum of anabolic and catabolic processes is balanced as in an adult individuum. These climax vegetations are considered sustainable, as long as there are no major disturbances in the environment. However, even if local conditions remain stable, we shall not forget about the impact of evolution, for instance the evolution of a species called *Homo sapiens* some 200,000 years ago in Africa that is today actively changing ecosystems all over the planet.

Sustainability and resilience in agro-ecosystems: Since the main focus of this article is on man-made agro-ecosystems, we may consider here a typical monoculture, viz. the cultivation of a single crop or plant species over a wide area and for several consecutive years. Generally, this practice is considered not to be sustainable, as it leads to a faster spread of diseases and soil degradation. Instead, crop rotation and diversification are accepted as agricultural measures to increase sustainability, allowing agro-ecosystems to respond to a perturbation or disturbance by resisting damage and recovering quickly (resilience). In this way the concepts of sustainability and resilience are closely linked. An agro-ecosystem is only sustainable if it resists damage and endures for a certain period of time.

How to manage agro-climax in a sustainable way? This latter aspect raises the question of how far man in general is able to achieve a kind of sustainable management? If we understand sustainability as the capacity to support or maintain a *status quo*, almost any human activity at the beginning can be seen as unsustainable, since it is a characteristic of human activity to adapt the environment to our own needs. However, this newly transformed environment (ecosystem) may reach a new climax state (for instance an agro-climax state). In some cases sustainability may be reached, in others not – at least in the long term. For instance, productivity of ecosystems is highest long before the climax state is reached, which is why in agro-ecosystems early succession-types instead of climax states dominate (Janssens et al., 2008). This type of cultivation practice does not in principle exclude sustainable management, but usually results in the exploitation of resources (e.g. soil nutrients), which then have to be added as fertilisers. Consequently, agro-ecosystems cannot be seen as closed systems. Nevertheless, natural ecosystems are also not closed, since energy (sunlight) and water (e.g. rain, river) enters these ecosystems from outside. In addition, ecosystems must obey the second law of thermodynamics, which states that in any closed system, the amount of entropy tends to increase. As a consequence, ecosystems exchange matter and energy with their surroundings. As a matter of fact, living systems (cells, organisms, and even ecosystems) are not in a state of equilibrium, but instead are dissipative systems that maintain their state of high complexity by causing a larger increase in the entropy of their environments (Stockar and Liu, 1999). Life achieves this by coupling the spontaneous processes of catabolism to the non-spontaneous processes of anabolism. In thermodynamic terms, metabolism maintains order by creating disorder (Demirel & Sandler, 2002). *Sustainability is a catabolic-anabolic tandem*: In this final sense, sustainability is the successful coupling of catabolic and anabolic processes. Even adding fertilizer and pesticides to an agro-ecosystem may be seen as an anabolic process that is necessary to maintain order. As long as the input by human activity ensures the survival of the agro-ecosystem, it may even be considered sustainable (using the term sustainability in the general sense mentioned above). Human activity, however, is determined by economic aspects and, hence, a certain agro-ecosystem will be maintained as long as it is profitable. If not profitable, the "environmental" conditions have changed and another, new climax state (vegetation) will be established by the farmer or will establish itself.

In conclusion, sustainability strongly depends on "environmental" conditions. If the "environmental" conditions remain almost stable, spontaneous catabolic processes are easier (more stable) coupled with non-spontaneous anabolic processes. Yet, these anabolic processes rely on the input of energy. Several energy resources may be considered. However, here only two representative examples are discussed: the fossil energy consumed by recent human activities and the "natural" light energy emitted by the sun. The fossil energy used by man to maintain e.g. agro-ecosystems (viz. creating order) results a.o. in the increase of atmospheric CO_2 concentrations (viz. creating disorder) with the consequence of global climate change and its impact on global ecosystems. Similarly, the development of photosynthesis to exploit the sunlight using H_2O as electron donor resulted in the release of O_2, leading to the GOE. Obviously, making new energy resources available may result in a serious disturbance of life, but life on Earth may be able to adapt. If the new energy resource, as in the case of sunlight, is – in human dimensions – eternally available, a new equilibrium may evolve, leading to sustainable ecosystems. If, however, as in case of fossil energy resources, their availability is limited, life (or in the case of man: lifestyle) relying on these resources may not reach a sustainable state in the long term.

In summary, sustainability is an ideal state in the area of conflict between environmental change, evolution of life and thermodynamic laws. It cannot be defined as a stable state, but as a state of relative stability during a certain but limited period of time. Sustainability strongly depends on a reliable energy resource that, in thermodynamic terms, allows order to be maintained in an open (eco-) system at the expense of the order of the environment.

3. Genetic background of agriculture and sustainability

In farming systems we are dealing with agro-diversity. This implies the use of a broad genetic basis at the landscape level. This diversity encompasses a large array of different species and within species a mixture or varieties/cultivars/clones. Eventually, we should encourage some heterozygous (say hybrid) status to the cultivars. Even with so called inbreeding species, hybrid combinations often prove to have superior field performances. In fruit cropping and forestry, quick progress can be achieved by cloning. As a result, there is a tendency to use the most rewarding clones on a large scale. If we want to averse risk in the long run, we should mix a minimum number of different clones to ensure enough genetic diversity and hence, homeostasis. Genetic material should then be adapted to the target area. If the target area is characterized by low soil fertility and/or difficult climatic conditions we have to breed according to low-input ideotypes (Janssens et al. 1989). If the environment is fertile and we want to achieve high yield we will breed along a high-input model. The critical issue is that this agro-climax environment is not constant but moving all the time, not so much because of climate change, but particularly because of market demand and regulations as well as advances in mechanisation and automation (even robotisation). Nowadays, many dairy farms are introducing automatic milking by robots. Milking frequency and concentrate feeding is steered by computers on an individual basis by the same token. Similarly, large vineyards and fruit orchards are increasingly turning to mechanical harvesting in order to reduce labour costs. This step is rendered possible by breeding animals or plants which will be easily treated mechanically. It all means that changing agro-climax conditions require quick adaptation of the genetic material and hence, of the pursued ideotype models.

In Australia, wheat scientists are selecting new genotypes with resistance against newly created rust races i.e. laboratory constructs, such as to be ready with adequate wheat cultivars at the outbreak of a new rust race. This strategy is unfortunately not extended to all modern ideotypes. If we look at the substantial agro-climax changes in Europe during the last 50 years, farmers have had to change from high fertilisation and pesticide levels into severely controlled demand driven supply schemes. This has been successful, particularly for nitrogen and for some of the more toxic pesticides.

In the Americas zero tillage became another spectacular success, in fact even more important than the earlier green revolution in India. This major breakthrough was rendered possible by the end of the patent protection for glyphosate-based herbicides and by the development of adapted tillage machinery in Brazil, and finally by the development of Round-up-Ready varieties (RR) for major field crops (soybean, maize, wheat, rapeseed, etc.). Interestingly, the genetic engineering originated from Europe (University of Ghent, Belgium) but was applied elsewhere because of GMO restrictions, the major reasons being that some of the RR lines might intercross with wild relatives and that the high levels of herbicides may in the end induce weed populations to become extremely aggressive.

On the other hand, experience shows that breeding for genotypes combining both wide environmental (geographic) and biotic adaptation is too much of the good. Recently, manioc breeders purposely selected against the mosaic virus and discovered later that the mosaic resistant lines tended to be susceptible to either the brown virus or bacterial wilt or both. In cotton breeding against boll worm a major breakthrough was achieved with the help of genetic engineering on the basis of *Bacillus thuringensis,* leading to spectacular results both in the Americas and in Asia, until the resistance of the newly developed BT lines regressed. Similar breakdowns are reported for BT maize lines either against *Busseola fusca* (stem borer) in South Africa or *Spodoptera frugiperda* (fall armyworm) in Puerto Rico.

One could conclude that plant breeders should on the one hand be ready to quickly adapt their ideotypes to changing agro-climax conditions, and, on the other hand, refrain from unrealistic goals like adaptation to a too wide target area and/or an unrealistic combination of all possible desirable traits (Janssens 1987).

Should we prefer perennial to annual crops in the future? If we want to strive towards more agricultural sustainability, there will be no other choice than moving massively from annual crops towards perennial crops, wherever possible (Janssens and Subramaniam 2000). Indeed, for most agricultural base products one could choose between annual and perennial crops (Annex 3). Perennial crops are not only input efficient but they also offer better eco-capacity in terms of eco-volume, micro-climate, litter fall and hence, soil fertility. Even a tree monocrop is notably better than an annual monocrop. The large majority of tree monocrops are associated with an herbaceous cover crop, preferably a leguminous crop. In addition, tree crop rotation is easy to implement. There will be a major challenge in this conversion process in that new mechanisation techniques, adapted to tree crops, need to be developed both for harvesting and pruning (op.cit.).

4. Growth efficiency is closely related to the efficiency of spatial colonisation by plants

Natural eco-systems maximize eco-volume per unit of available energy. Under agricultural systems, the desired produce will be maximized at the expense of eco-volume, as can be seen with sugar cane in Mexico (Annex 2). The different ways chosen by plants under different agro-ecological conditions are there to ensure species survival and perpetuation. Under difficult situations plants will try to develop highly specialized reserve organs with highly concentrated energy storage means. When considering eco-volume as a major characteristic of each crop morphotype or each vegetation type rather than biomass, it follows that energy and input flows should be divided by eco-volume. How large can an eco-volume be developed per unit of water or per unit of solar input, per each season of the year? Eventually, the crop morphotypes/vegetation types with largest RUE (rain use efficiency), WUE (water use efficiency) or NUE (nutrient use efficiency) on an eco-volume basis will take the lead in a particular environment (Figure 1). Plant growth is in fact the development of a maximum eco-volume with a minimum of energy. In turn, this eco-volume will increase with improved use of rain and nutrients. Hence, eco-volume will eventually lead towards better environmental efficiency.

Therefore, the best adapted eco-system will follow the principle of minimum energy and develop the greatest eco-volume (in space), which in turn will produce the largest biomass per unit of surface in agreement with the maximum power theory of Odum (1995).

Maximum Empower Principle

This optimizing principle is one of the most daring aspects of energy analysis. Having its roots in work by Lotka (1922), the Maximum Empower Principle claims that all self-organizing systems tend to maximize their rate of energy use or empower (Odum, 1995).

That is, "ecosystems, earth systems, astronomical systems, and possibly all systems are organized in hierarchies, because this design maximizes useful energy processing". Thus, this principle can determine which species or ecosystems or any system will survive.

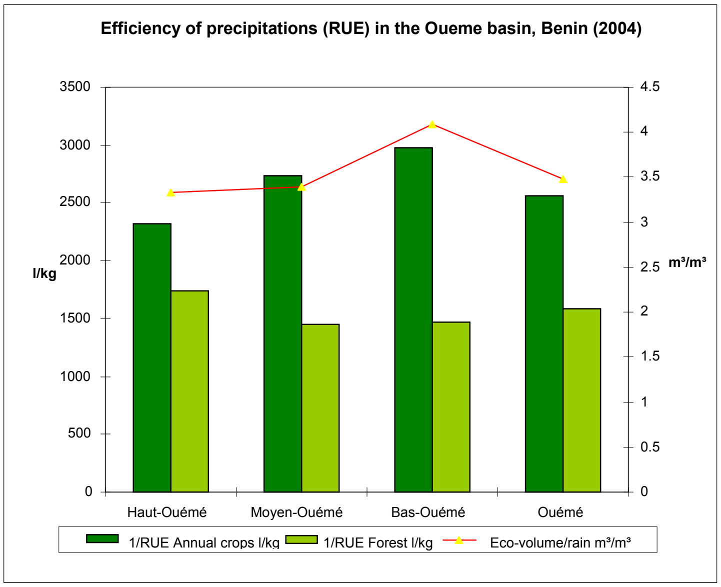

Figure 1. Rain use efficiency and eco-volume/rain rate in the Oueme basin, Benin

5. Input efficiency, sustainability and bio-economics

Sustainability: The term "sustainability" and its meaning were always seen as a principle for production in forest and agricultural sciences as a long-term aspect since the implementation and foundation of the first agricultural faculties and universities in the 19th century as a reaction to severe degradation processes in the rural areas of European countries. Sustainability is seen as a principle of farm management – especially in typical European peasant farming systems, where the peasants aim to maintain the fertility of the soil for the coming generations (von Dietze, 1967). Within this historic perspective, the Brundtland-Report (1987) re-assesses the intergenerational justice aspect, while defining sustainable development as the "ability to satisfy present needs without curtailing the ability of future generations to satisfy theirs" (cited in EU-Report on Development, 2012). This is nothing more than the long-term aspect of production intensity without overusing natural resources. Such overuse leads to scarcity of natural resources. This scenario was first brought into discussion by the "Meadow-Report" (Club of Rome), the catastrophic predictions of which could fortunately not be verified.

Misuse of sustainability: Publications by prestigious institutions are full of mainstream opinions considering sustainable use or overuse and deterioration of natural resources and their costs for society. In the European Report on Development (2012) one can find a tabular presentation of "the costs of business as usual for the future: some illustrative examples". The table is divided into three parts, where examples from international publications are cited for environmental costs, economic costs and social costs, all examples support the favoured tendency of the publication in question without considering publications with contrary findings, e.g.:

1. **Environmental costs:** "we live in the anthropocene epoch, an environment of which there is no historical experience" (op. cit.). Who would compare historical epochs without considering the circumstances and particular conditions of each epoch? This "golden principle of historical research" seems to have the character of a tautology.
2. **Economic costs**: "Failure to act on climate change will reduce world GDP by 20%" (op.cit.); this unilateral estimation has no scientific calculation.
3. **Social costs**: "Agriculture is currently not intensified in Africa, but applying the technology behind the Green Revolution will not sustainably produce food for 9 billion people" (op.cit.); the first statement is simply wrong – for the second statement one can find many contrary findings in the scientific literature (e.g. FAO - 2012).

Many publications on sustainability or "resource use" overlook the three generally accepted strategies of achieving environmental, economic and social sustainability as stated in the "Agenda 21" of the UN-Earth summit in Rio de Janeiro (UNCED 1992):

- **Efficiency strategy** is the most important strategy and refers to innovations and technology that improve efficiency or productivity, or more generally – the input/output relation in using resources for a certain purpose e.g. if a new rice variety has higher yields (ceteris paribus), breeding has improved productivity of land use.
- **Consistency strategy** refers to possible resource saving effects of closing cycles in using resources – if it is economically, socially and environmentally feasible. Re-use of water is a very good example and well-studied, e.g. by FAO (2010).
- **Sufficiency strategy** refers to the behaviour of people in overusing resources, very often because of the fact that the consumer prices are lower than the social prices (a worldwide problem with water for irrigation where very often the prices are subsidized). Behaviour in resource use can be changed by means of education, higher prices or legal measures.

Inclusive societies against inequity driven sustainability: In the EU Report mentioned above, a further definition is brought into discussion (European Union 20121987): ..."we define inclusive and sustainable growth broadly as a type of growth that is consistent with the natural cycles that allow ecosystems to replenish resources, absorb waste, and maintain adequate conditions for life; and that at the same time offers all people an equal opportunity to participate in and enjoy the benefits of increased wealth". As it refers to sustainability of ecosystem services and "eternal" duration of wellbeing it is only a re-wording of the three dimensions of development as expressed in Agenda 21, bearing in mind that economic growth is the basis of development. EU introduced "inclusiveness" as a notion referring to the participation of current generations in sharing global wealth. "In addition, more equitable or inclusive societies tend to perform better economically and politically than unequal ones".

The report mentions, in addition to the publications of UNDP and the World Bank, that inequality is something like "wasted potential" and could give rise to conflict and violence in extreme forms. However, if we follow historical experience and the different opinions of serious scientists (von Weizsäcker, 2000) it seems likely that a certain level of inequity is necessary for economic growth.

Intergenerational justice: When we speak about the productivity of ecosystems using the notion of "ecosystem services" we address the potential of natural resources in a anthropocentric view postulating a long-term "steady state" (Walter 1990); and this postulate includes the aspect of "intergenerational justice". We come back to the definition of sustainable development claimed in the famous "Brundtland – Report" (Brundtland-Commission 1987), which defines sustainable development as the ability to satisfy present needs without curtailing the ability of future generations to satisfy theirs (see above). Hence, intergenerational justice must take into account both present and future generations.

Dynamic equilibrium and entropy: The two basic laws of thermodynamics and entropy give us the "highway striping" for resource management following a concept of "long-lasting-view" (the fashionable word is "sustainability") assuming that the state of dynamic equilibrium should have a minimum of entropy production. The material balance principle (equation) is: A= B+C+D; where B+C+D represents the discharge flows to the environment, and where the ecosystem energy requirements (A) are nearer to the balance (or "equilibrium flow"). Therefore, if we have sufficient energy, we can resort to all kinds of resource use (for food production, bioenergy etc.). This clarifies the importance of energy policy (Gaese 2012).

Regulating global carrying capacity through energy input: The density of the world's population and its energy consumption are far higher today than during the Neolithic period. Mohr (2000) calls it the "Neolithic Green Revolution". Ecosystem services were reduced in that time, but simultaneously the ability of humans to dominate negative externalities through technology and management rose (Gaese, 2012 and Mohr, 2000). Increased "carrying capacity" enabled the world population to increase from app. 5 M humans (8000 B.C.) to 100 M (4000 B.C.) and 200 M humans around year 0. The industrial revolution caused a similar boost to population growth. Today more than 7 billion humans need to be supplied with resources. The sustainability question is: Are we able to maintain the high artificial carrying capacity and for how long in the future? Ecosystems today are very far from "minimum entropy production and require a permanent energy input to be maintained. These systems are far from the "self-regulation" of the original systems. How can we maintain the balance?

Steady state or equilibrium in flow: The notion of "steady state" was used by the internationally renowned botanist Heinrich Walter (former professor of botany at the University of Stuttgart-Hohenheim) – who founded the "ecology of plant communities" (see Walter 1990) in the nineteen-eighties. In a larger sense steady state has something to do with the "equilibrium in flow" as a dynamic flow which was theoretically analysed and postulated as a principle of material flow by Aristotle. As pointed out with reference to climax vegetation in eco-systems such as savannahs, grassland, etc. (see above), these represent a quasi-equilibrium or "steady" state (Walter 1993). Indeed, these climax vegetation types must be considered sustainable, in spite of periodical and inherent fire disturbances. It seems plausible that land use systems which do not disturb the quasi-equilibrium state could be seen as sustainable land use systems.

Recent intensification efforts in animal husbandry: Gaese (2006) verifies the ecosystem-friendly extensive production system in animal husbandry where the comparative advantages of production costs are considerable compared to European meat production systems. On the contrary, feedlots are intensive production systems. They represent a new tendency in meat producing countries with grassland like Argentina, Brazil and Uruguay. Feedlots require concentrated food production, high energy supply, high transportation costs, high concentrated and overused resources like water and land with high environmental impacts. The land use change from extensive to intensive animal husbandry systems is environmentally highly problematic, as the sum of anabolic and catabolic processes is out of balance with such high intensity. However, we can now observe strong development in sylvo-pastoral cattle ranches in the tropics. These offer advantages both from an environmental and from an economic viewpoint. Indeed, beef fattening will allow highly desirable cash-flow three years after the establishment of the forest plantation.

Precision farming and zero-tillage: In crop production systems there is a general tendency for higher intensity production processes, and catabolic processes are compensated by technical progress (innovations). The highest standard is achieved with so-called "precision farming" (preferably in combination with zero-tillage), a technology where catabolic processes are controlled and minimized by the system, following the strategy of increasing resource use efficiency (OECD, 2010). Branscheid (2012) mentions indicators for sustainability in meat production and consumption.

Increased input efficiency through technology advances and resource scarcity: The aforementioned strategies for decreasing resource abuse and stress are undoubtedly the most important ways to reduce resource consumption and to come nearer to an ecological "equilibrium in flow", or sustainability. A further important aspect is the interaction between economic growth and resource use: it is very probable that higher economic growth leads to less overuse of resources: The interaction between economic growth and less overuse of resources is *rebus sic stantibus* very probable (technology changes induced by higher prices for other production factors e.g. labour):

1. High prices of resources (land, water, energy etc.) will be a signal for investors to invest in technologies with lower resource requirements; this should also encourage politicians to manage the "Ordnungspolitik" (guarantee for the functioning of free markets).
2. Higher investments in research and development (R&D) will generate technology to substitute resource consumption.
3. This is also important for poor countries, since "the demand for environmental goods and services has a high elasticity in relation to demand". This means there is a positive relation between economic growth and environmental protection.

Sustainability and financial short thinking

In a publication dealing with the recent instability of the monetary system, the Club of Rome (Lietaerd et al., 2013) mentioned five characteristics which trigger behaviour that is directly incompatible with sustainability

1. Amplification of boom and bust cycles: Banks are said to amplify the business cycle towards boom or bust.
2. Short-term thinking, manifested by discounting cash flows in investment feasibility studies.
3. Compulsory growth: exponential growth is said to be unsustainable in a finite world.
4. Concentration of wealth: positive interest rates are said to generate inequalities, which will impoverish middle classes worldwide.
5. Devaluation of social capital: money tends to promote selfish and non-collaborative behaviour ("money is not value neutral").

While all these aspects recognize only a critical and negative view of sustainability, one of these five "characteristics" shall be analysed in a little more detail: the problem of "short-term thinking" which seems to be normal in everyday life. Short-term thinking is seemingly typical for decisions of small farmers (or about 70% of all farmers worldwide according to FAO). The reason for this behaviour is very simple: small farmers are not able to accumulate capital for investments – they have to concentrate on how to survive today and tomorrow. Short-term thinking will discount future values and intergenerational justice.

Consumption rate of interest and social rate of time preference: The aforementioned Brundtland-Report (1987) gives a definition of sustainability focussing on the intergenerational long-term aspect meaning the "ability to satisfy present needs without curtailing the ability of future generations to satisfy theirs". Using the opportunity costs of capital in resource-protecting projects, where very often inflows are registered in the far future, whereas investments (outflow) are realized at the beginning of the implementation phase, the project would never be feasible based on calculating the "Net Present Value". The high opportunity costs of capital (high interest rates) would discount the future values of inflow (e.g. rehabilitation of a watershed). It is very clear that we have to favour a low interest rate to make such projects and activities possible, as they would not be considered if we were not able to think in long-term scenarios. Known as "long-term thinkers" and "sustainability-fans", the less developed an economy and the scarcer the production factor capital, the higher the interest rate (or cost of capital). Entrepreneurs normally think in shorter periods as it is beneficial for social wellbeing. From a scientific perspective we should always use the "accounting rate of interest", representing the opportunity costs of production factor capital. Nevertheless, as this would not allow important projects like reforestation or rehabilitation of landscape units (or e.g. rehabilitation of ecosystem services), in projects where the so-called "social time" preference is low, the principle of accounting rate of interest cannot be applied. Therefore we have to focus on a "consumption rate of interest". Consumption rate of interest requires a normative decision; we have to estimate the "social benefit" and the "social time preference" of that activity (project). OECD (1995), cited in FAO Wealth of Waste (2010), developed a formula for estimating social time preference:

$$S = P+U \times G;$$

Where:
S = social rate of time preference
P = pure rate of time preference, the rate at which utility is discounted
U = rate at which marginal utility declines as consumption increases
G = expected growth in consumption per head

For developed countries (relatively low opportunity cost of capital), OECD recommends the parameters P= 2%; U = 1.5%; G = 2% giving a value for S of 2.03%. In a poor developing country with good growth prospects it is plausible to substitute values of P = 5% and G = 3%, giving S = 5.045%. For poor countries with poor or negative growth prospects, the higher value for P would be wholly or partly offset by low or negative values of G.

Even though estimating social time preference may be appropriate for poor developing countries with low economic growth rate, considering their future development and the wellbeing of future generations, this will always be a normative act using the "Net Present Value" as an indicator for economic development. If the development process depends on the activity of private investors and entrepreneurs the "decision makers" have to take into account that they are basing their decisions on future time-periods that are shorter than is often economically recommendable. In the long-run, economic sustainability of the whole economy depends on sustainable management of enterprise; time preference calculations as above cannot be sustainable financially. Short-term thinking is important as an engine for accumulation of capital, which is a long-term flow per se. In a wider sense it may be seen as sustainable to a point.

In other words: if society needs the rehabilitation of a watershed – a project which would not be considered in a political decision process (because of the discounted future values and therefore low or no financial return on the investment) – the investment has to be decided without proven sustainability. Potentially, this may result in an intergenerational threat. Consumption rate of interest (or social time preference) is a normative factor and means abnegation (abstinence) of possible inflow for the benefit of future inflows – or future generations. Another aspect is that in contradiction to the intergenerational argument in terms of financial flows and accumulation of capital, all heritage traded to the next generation are values accumulated sometimes over generations. This fact may be considered if moral arguments are used in the discussion on intergenerational obligation.

Politicians frequently argue that "we solve our problems today and the future generations have to solve their problems (even if we create them). Today, we may not have the technique(s) to solve certain problems, but tomorrow they may be available". What is the consequence of such argumentation for sustainable approaches? Today, an investment into a sustainable agricultural practice may, unfortunately, not be advisable for economic reasons. Tomorrow, it will be realised even at higher costs. However, how can such a strategy be successful? In order to understand this apparent contradiction, we must remember a basic aspect of money: Money per se has no value.

You cannot eat it and it won't warm you up. It is just a means to buy something. However, what do we buy first of all, when not considering a positive cash flow in trade? What we need, especially right now. This restriction here and now, as already mentioned, is the basis for the decisions of small farmers, but also of other decision-makers that are unable or unwilling to accumulate capital for investments. Or, in other words, when considering that 70% of all farmers worldwide according to FAO (must) follow this practice, then an investment in the future must be regarded as a kind of luxury. This creates an interesting question: Is our discussion of sustainability a luxury discussion or an absolute necessity? The discussion above clearly indicates the economic constraints with respect to the realisation of any project, but it does not in any way question the necessity of a certain measure. In addition, we should not forget that a certain measure to maintain/achieve sustainability seems today the best option, but is it the best option tomorrow, when the problem must be solved (meaning that the problem is so pressing that it cannot be left for the next generation)? Here, we have to keep in mind, as mentioned above, the view of geologists and astronomers on sustainability that most phenomena are time specific. In this respect it must be concluded that sustainability is not only in conflict with economic constraints but also with the need of innovative approaches at a given time. This does not explicitly exclude the possibility that realising a sustainable approach per se may represent an innovative measure.

Conclusions

1. The rate of catabolic processes should not exceed anabolic processes; the capability of regeneration of ecosystem services must be sustained.
2. The tempo of anthropogenic emissions (or interventions) into the environment must be in balance with the tempo of environmental reaction and environmental processes.
3. Obligation for governments: definition of environmental targets and rules and regulations for enterprises in all sectors (examples: eco-audit of enterprises).
4. The fashion is concentrated on the "Greenhouse Gas" CO_2 and a supposed climate change which is not yet proved (it might only exist in the imagination of pessimists) – Revocation in IPCC-Report 2012.
5. Soils and their sustainable preservation are much more important than CO_2 and other greenhouse gases (in Germany we lose daily 100 ha of agricultural land because of irresponsible use of machinery).
6. We need to achieve a "dynamic equilibrium" in the ecosystems, which could be measured as a status, in which entropy production is at a minimum (see above). Therefore, the discussion on "ecosystem services" and their measurement initiated by institutions dealing with Economics of Ecosystems and Biodiversity (TEEB 2014) is very valuable.
7. A rule for the economic system: the carbon credit system should be replaced ASAP by more relevant sustainability drivers.

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Annexes

Annex 1: List of selected drivers conducive to Agricultural sustainability

Sustainability driver	Upgrading	Balance*	Degrading	Remarks
1.Psychology	Education, Character training	>	Autodestruction Schizophrenia	Human brain mobilizes ¼ of metabolic energy
1.Philosophy	Dialectic thinking	>	Self-centered mainstream thinking	Closed integrist schools of thought
1.Religion	Soul liberation	>	Dogmatic fear	Cf. Meister Eckhart
1.Politics	Teleonomic Multiform structures	>	Uniform blocks (dictatorship etc.)	Efficient in the short run but not sustainable
1.Organic-social entities	Integration	>	Sum of components	Integrism = amplification of one component
1.Arts	Harmonious music/painting/ architecture	>	Fancy fashion, mainstream mimetism	
2.Metabolism	Anabolism	>	Katabolism	
2.Biochemical	H_2	>	O_2	H_2O = survival buffer H_2 = major anti-oxidative driver
2.Photosynthesis	$(CH_2)x$	>	CO_2	PAR made more efficient in hot environment. Heat loss through entropy somewhat alleviated
2.Proteins	(NH)	>	NO_x	
2.Hormonal regulation	Homeostasis	>	Unbalanced	See doping, drugs, unilateral use of phytohormones
6.Genetics	Outcrossing	>	Inbreeding	Hybrid vigour degeneration of pharaoh civilization, "cousinage"
10. Which crops?	Perennial crops	>	Annual crops	Saving resources through tree crops and higher eco-volume

Annex 1: List of selected drivers conducive to Agricultural sustainability (continuation)

3. Spatial efficiency	Veco/Vbio	>>>	100	Minimum energy for spatial maximum
11. Input efficiency	Compounded if not catalytic effect	>>>	Energy and value of input	
12.Economic return	Economic profit of cropped land	>	Loss of eco-system services	Hence, marginal crops should be abandoned
4. Agro-climax	Veco/Vbio	<<<	100	Maximum (power & Vbio)/m² and Minimum Veco
5.Farming	Concentration of energy and resources	>	Dilution of energy and resources	Modern precision systems more efficient at diluting e.g. drip irrigation under plastic tunnels
5.Farm residues	Added value through transformation	>	Wasted farm residues	Green chemistry and processing
7.Energy	Output (O)	>	Input (I)	Non-renewable input (cf. Energy analysis by Odum)
7.Carbon	Carbon sequestration	>	CO_2 loss i.e. energy loss	Rate of return within landscapes to be improved
9.Nitrogen	Internal N supply	>	External N input	N fertilisers account for > 1/2 the energy inputs of most crops.
8.Water	Green water	>	Blue water + red (fossil) water	Rate of return w/n watersheds to be improved
8. Reversibility and resilience	Reversibility and resilience	>	Agro-ecosystem drift	See Chile and Rodrigo
9.Agrosphere	Vitality of organic matter	>	Environmental "load" of abiotic inputs	Dilution/neutralizing capacity of agrosphere
9. Best agricult. practices	Green light	>	(Red & yellow) lights	Red light system
10. Sustainable, intensive crop husbandry	Nutrient uptake	>	Nutrient losses	IPN, permanent diagnosis, input efficiency
	Humification	>	Mineralization	

* Balanced flow + contingency surplus

Annex 2: Estimates of eco-volume and bio-volume of sugar cane in Mexico, Chiapas, Huixtla (average of 6 years)

	Yield (fresh matter in t/ha/year)			Biometrical characteristics of sugar cane stand					
	Cane	Cane tops	Total	Eco-height (d)	Basal Area (BA) m²/ha	Eco-volume V_{eco} (m³/ha)	Bio-volume (m³/ha) = BA * d	Wesenberg (w) (V_{eco}/V_{bio})	C_i = 100/w (%)
Green cane	125	18.7	143.7	2.46	131	24600	322.3	76.3	1.3
Burn 1x	96	14.4	110.4	2.09	97.5	20900	203.8	102.6	1
Burn 2x	89	13.3	102.3	1.97	72.3	19700	142.4	138.3	0.7
	Dry matter yield (t/ha/year)			Energy content					
	Cane	Cane tops	Total	MJ/kg dry matter	Yield (GJ/ha) Output	Yield (GJ/ha) Loss	MJ/m³ eco-volume	MJ/m³ bio-volume	
Green cane	41.7	6.3	48	18	864	0	35.1	2681	
Burn 1x	32	4.8	36.8	18	662.4	201.6	31.7	3250	
Burn 2x	29.7	4.5	34.2	18	615.6	248.4	31.2	4323	
					Maximum power law			**Agricultural concentration**	**Bio-industrial concentration**
Concentration path									
Site	Atmosphere					**Eco-volume**	**Bio-volume**	**Saccharose**	**Bio-ethanol**
Active ingredient	CO_2 350 ppm					**$(CH_2)n$**		**$C_{12}H_{22}O_1$**	**C_2H_5OH**
Energy status	0 MJ/m³					**> 30 MJ/m³**	**> 2500 MJ/m³**	**17MJ/kg**	**30 MJ/kg**

Source: Estimated after Toledo Toldedo, E. et al. 2006

Annex 3: Comparing annual to perennial crops for major agricultural categories and functions (Janssens et al. 2000)

Agricultural category	**Subcategory**	**Annual crops**	**Permanent crops**
Carbohydrates	Starch	Cereals, Roots & Tubers	Plantain, Bread tree, Jackfruit, Treculia africana, Sago palm, Ensete banana, Chestnut, etc.
	Sugar	Sugar beet, Sugar cane*, Sweet corn, sweet sorghum etc.	Borassus flabellifer, Sugar maple, Sugar palm, Kitul palm, Nypa palm, Date palm, Chilean sugar palm, etc.
Protein		Pulses, (Pigeonpea*)	Avocado, Baobab Leguminous tree crops: Tamarind, Caroub tree, Bean tree, Parkia, Quamachil (?)
Lipid		Peanut, Soyabean, Sunflower, Sesame, Cotton, Rape, Flax, Safflower, etc.	Oil palm, Coconut palm, Babassu palm, Karite, Avocado, African pear, Olive tree, Castor oil, Aleurites, Pejibaye, Balanites, Argan tree
Vege-tables	Leaf	Salad, spinach	Baobab, Moringa, Sesban, Mulberry
	Other	Bulbs, Fruit vegetables etc.	Palm heart (Palmetto etc.)
Fruit	Nut	Peanut, Bambara nut	Cashew nut, Brazil nut, Pistachio, Hazel nut, Almond, Macadamia nut, Walnut, etc.
	Other	Fruit vegetables (as above)	Annonaceae, Sapindaceae, Sapotaceae, Rosaceae, Passifloraceae, Rutaceae, Moraceae, etc.
Fuel wood		Limited	Numerous
Grazing		Numerous	Numerous. Underexploited
Fibre		Cotton, Flax, Hemp, Ramie, Jute, Kenaf	Kapok, Musa textilis, Agave, Bombax ceiba, Gossypium arboreum, Raphia palm
Rubber		Guayule	Rubber tree, Guttaperche, Euphorbia tirucalli, Ficus elastica
Insecticidal use		Tobacco, Pyrethrum*,	Neem, Derris, Aglaia, Mammey apple, etc.
Spices/ Flavours		Ginger, Chili*, Turmeric, Vanilla*, Fennel, Hops*	Black pepper, Clove, Cinnamon, Nutmeg, Curry leaf tree
Essentialoils/ Perfumes		Mint, Chamomile, Lavender*, Rosemary	Eucalyptus, Rose, Artabotrys, Jasmine, Cajaput tree
Dyes		Indigo, Safflower, Woad	Annatto, Campeachy wood, Henna

*Perennial crops grown facultatively as annual crops