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CONCEPT AND MEASUREMENT OF SUSTAINABILITY IN AGRICULTURE

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1. Introduction

It is with great pleasure that I accepted the invitation to attend the fourth African Farm Management Conference at the University of Stellenbosch and to be a keynote speaker. It is great to be here, in this wonderful environment, and to reflect with you on the great issues of our time, in casu sustainability in agriculture.

Many of you may think that sustainability is a rather loose concept, with more or less everybody having his/ her own definition. However, one cannot deny that it is an important concept, that it is not just a fad nor just fashionable to speak about it, hoping that tomorrow some other concept will emerge which will draw our attention and focus our energy. I firmly believe that sustainability as a concept and as an issue is here to stay and to remain with us. Nevertheless, of course, it will have a different meaning to different people in light of the constraints of the environment and the policy framework in which each is situated.

While pollution and environmental degradation caused by the assault on the environment results from poverty in the developing countries, it is the result of wealth in the developed countries (Mellor, 1988). In other words, the sustainability problem in agriculture arises out of different socio-economic circumstances; activities in both the developed and developing countries. For most poor people sustainability is not an issue as they try to make ends meet every day, without worrying too much about next week, let alone next year and the future generations. However, as researchers and academics we have a special responsibility to look ahead further than others do, and to ask ourselves where we are going and what we will end up with. This requires taking a stand some distance from day-to-day reality and from the concerns of this generation. As will become clearer further on, sustainability has to do mainly with the rights of the future population, and they do not have a say in today's matters.

2. The concept of sustainability in agriculture

A lot has already been written about sustainability and sustainable development. In the annex I list definitions of sustainability which Driesen and Beerlandt (1994) found in their study of the relationship between sustainable agriculture and biotechnology. I also refer to the excellent article by Sharachchandra M. Lélé (1991) about sustainable development where he distinguishes between sustainability on the one hand and development on the other, and whereby sustainability has three dimensions:

Literal sustainability, meaning sustaining something, which raises the question of "what is to be sustained," "for whom?" and "how long?" In terms of economics, it means that whatever economic activity one undertakes must be profitable in the sense that the benefits derived from the activity at least equal the (resource) costs involved. Net value must be added after accounting for the value of all resources that are used, including the future value or the time value of resources. This last item is particularly difficult, as markets are not very good at determining the future value of resources, particularly non-renewable resources. This is one of the cases of market failure and I will come back to it. But let us retain for the moment that

sustainability first of all requires that any economic activity that is undertaken must be profitable, whatever criteria of profitability one likes to adopt. Non-profitable activities are per definition not sustainable and one often tends to forget that. A non-profitable enterprise is doomed to disappear. Making a profit is thus a must for an enterprise to survive, let alone to grow.

Ecological sustainability. Most proponents of sustainability refer to this concept, meaning "the existence of the ecological conditions necessary to support human life at a specified level of well-being through future generations". In fact, the concept of sustainability originated in the context of renewable resources such as forests or fisheries. The term sustainable development came into prominence in 1980, when the International Union for the Conservation of Nature and Natural Resources (IUCN) presented the World Conservation Strategy (WCS) with "the overall aim of achieving sustainable development through the conservation of living resources" (Sarachchandra M. Lélé, 1991).

The WCS suggested three ecological principles for ecological sustainability (IUCN, 1980):

- Maintenance of essential ecological process and life-support systems.
- The preservation of genetic diversity.
- The sustainable utilisation of species and resources.

These principles notably lack precision and have become something of a cliché, because "maintenance", "preservation" and "sustainable utilisation" all need to be defined clearly in order to have real meaning. Ecological sustainability needs to distinguish between renewable resources, non-renewable resources and environmental processes crucial to the maintenance of life, particularly human life. When agricultural scientists talk about sustainability, they usually refer in fact to ecological sustainability only.

Social sustainability. This has to do with sustaining the social basis of human life. It has to do with the ability to maintain desired social values, traditions, institutions, cultures, or other social characteristics. Political, institutional, cultural and social structures need to be maintained for the social peace that is essential for survival. Again, this is a loose, nebulous concept that needs a precise definition and content. In its extreme, a war or genocide that destroys human society is clearly an example of social unsustainability and it often has its roots in economic and/or ecological unsustainability. Rwanda's genocide, according to some authors (Maton and Van Bauwel, 1996), has its roots in a system of unsustainable agriculture with too many people on the land to support survival. Already in 1944 and 1946, J.P. Harroy warned against the ecological unsustainability of Rwanda's agriculture and proposed massive emigration to neighbouring countries, in particular Congo and Tanzania.

Sustainable agriculture finds its roots in ecological sustainability but also has links with economic and social sustainability. Sustainable agriculture must simultaneously provide fair returns to farmers, satisfy the food and fibre needs of the non-agricultural population, maintain the ecological productive resource base and preserve social stability and peace in society. For some (ecologists), sustainable agriculture is synonymous with low-input agriculture (LEISA) or organic farming. Nevertheless, as Vernon Ruttan frequently puts it, sustainability is just not enough for many developing countries. With, for instance, population in sub-Sahara Africa growing at 3% per year, and with many people poorly fed or underfed, agricultural production needs to grow by at least 4% annually over the coming decades. This is why Michel Griffon from CIRAD France is calling for a doubly green

revolution. Sustainability needs to go hand in hand with strong agricultural growth. As the land frontiers are either closed, or rapidly closing in many countries, important agricultural intensification, with yield increases per unit of land in the order of 3% or more per year, is called for. This is only possible with green revolution type technology - greater use of high yielding varieties, chemical fertilisers and pesticides and a massive increase of irrigation in the 21st century. One could dare say that LEISA will not be sustainable, particularly from an economic and social perspective, while high external input agriculture may not be ecologically sustainable. Moreover, this just shows how sustainability is a complex matter and a tremendous challenge.

Let me just conclude by saying that sustainability is clearly not enough - it must be coupled with development. And the concept of sustainable development as defined by the World Commission on Environment and Development (WCED) in 1987 means "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This latter part of the definition clearly refers to ecological and social sustainability.

This brings me to Richard B. Norgaard's (1991) contention that sustainability is first of all an issue of intergenerational equity, a redistribution of rights or a transfer of assets to future generations. He points to the fallacy of economists who have distorted the sustainability discourse with efficiency arguments, which implicitly assume that current generations hold all the rights to resources. In this respect, lowering the discount rate in project analysis to give greater weight to future benefits, and thus to future generations, cannot lead to sustainability, just as, in his view, greater efficiency of present renewable resource use does not fundamentally contribute to sustainability. In his view society needs a priori to decide that future generations have a right to non-renewable resources (such as biodiversity) and thus needs to set aside part of these resources. Saving these resources for future generations is thus a political decision, i.e. to acknowledge the right of future generations. In this sense, sustainability in his view is an issue of intergenerational equity, a redistribution of rights or a transfer of assets to future generations, which redefines the efficient allocation of resources. Efficiency arguments all implicitly assume that current generations hold all rights to resources. Moreover, this is why, in his view, sustainability is not an issue of a more efficient use of resources or of the lowering of the discount rate in project analysis. The role of economists is then limited to informing the political process of the impacts of different equity decisions and the most effective ways of reaching them.

Most economists disagree with Norgaard, but he certainly has a point. Suffice it to point out that even exceptionally low discount rates, like 2%, make benefits beyond the first 100 years irrelevant as the present worth factor becomes very low (for $n = 100$, at 2%, it is 0,138 exactly; for $i = 5\%$, $n = 100$, it is 0,0076). Even in conventional project analysis, it is common practice to limit the analysis to the first thirty years (Gittinger, 1982). Thus, in our common way of doing things, we limit ourselves to the interest of the next 2 to 3 generations at most. Certainly sustainability as such cannot be limited to the next three generations, and doomsday follow after that. I now come to the measurement of sustainability.

3. The measurement of sustainability

3.1 *Sustainable food crop production*

In what follows, we will concentrate on the concept of ecological sustainability. One of the great challenges of African agriculture in the humid and sub-humid areas is to develop a

sustainable farming system for annual food crops. The only sustainable farming systems where one can grow a crop year after year and maintain the productive resource base (soil fertility) without recourse to fallow, have been until now tree crops (oil palm, rubber, coffee, tea, cocoa) or tree crop based systems.[1] This is why there is nowadays such an emphasis on agro-forestry systems or agro-sylvo-pastoral systems, as a potentially sustainable food crop system will in all likelihood be an association of annual food crops and perennial trees or shrubs. Alley cropping as pioneered by IITA (Kang, Wilson and Lawson, 1984) is such a sustainable system, but its adoption is very slow because it takes at least 4 years before the beneficial effect on soil organic matter and soil fertility is evident and the system thus becomes "profitable". The problem is that most farmers abandon the system well before that. Moreover, investment in soil fertility maintenance only makes sense if one has tenure to the land, which is usually not the case in African smallholder agriculture. In most areas, planting trees on the land is a form of claiming land ownership that is not permitted. Thus the only successful agro-forestry systems for food crop production today are those where there is strong demand for the wood and/or leaves, either as animal fodder in the dry season, as firewood, stakes for staked beans or yams, for construction, etc.

It should be noted that while chemical fertilisers always help to maintain and enhance soil fertility, they are usually insufficient alone to maintain soil fertility, even in large doses, because of loss of soil organic matter coupled with weed infestation, particularly Imperata Cylindrica. The experience is that there is an important synergistic effect between organic (from agro-forestry) and inorganic fertilisers in agro-forestry systems in the tropics.

One of the critical issues with respect to sustainable agriculture in developing countries is which land will be suitable for massive increases in production intensity with high productivity to input ratios, and which land can be used in a more extensive way (Mellor, 1990). Massive poverty in rural areas of developing countries is a grossly underrated source of unsustainable agricultural production. Massive poverty pushes people into shifting cultivation or into the marginally dry areas, where they practice unsustainable land use. Poverty accounts for a substantial proportion of the loss of tropical forest.

We can conclude this section by saying that the first priority in African food crop agriculture is the elaboration of a viable and sustainable annual food crop production system which can be intensified and which obviates the need for fallow and thus eliminates shifting cultivation. Such a system could still include a managed fallow as part of the crop rotation. In fact, most recent research efforts at, for instance, IITA are on short rotation one to two year fallow with legume crops (Mucuna, Pueraria, Crotolaria) as live green mulches which restore soil fertility rapidly. Secondly, we should always realise that poverty is the root cause of unsustainable agricultural production in developing countries. Combating poverty will also reduce environmental degradation.

[1] The only sustainable food crop production system in the tropics is in fact a rice paddy. Some rice paddies in Thailand or Indonesia are over 500 years old, and they produce a crop year after year. With the irrigation water, soil nutrients coming from erosion run-off are brought into the paddy, the straw is usually incorporated in the soil after the harvest and chemical fertilisers are added to make up for any nutrient deficiencies. Also, paddy soils are usually rich in clay and loam, and soil organic matter plays a less prominent role in the maintenance of soil fertility.

3.2 *Measures of sustainability*

As in most cases we do not yet know precisely what constitutes a sustainable farming system, one relies on indirect measures of sustainability. All that is required for now is that these measures move in the right direction, sustainability itself remaining elusive and ill defined.

Examples of such measures are:

- % of soil organic matter in the soil.
- Use of chemical fertilisers and pesticides per unit of area and per year.
- Measures of biodiversity.
- Production of pollutants and greenhouse gases.
- Part of the area set aside as nature reserves, wild parks or conservation reserves in a region.
- Tons of erosion run-off per unit of area and per year.
- Replacement of non-renewable resources with renewable resources.

The EUROSTAT report "Indicators of Sustainable Development" (1997) contains a long list of economic, social, environmental and institutional indicators of sustainable development, but does not specify at which level the indicators satisfy the criteria of sustainable development.

In Europe it is now imperative for sustainability purposes that the use of chemical fertilisers and pesticides show a long term declining trend. However, nobody can tell us what will be acceptable in terms of chemical fertiliser and pesticide use in a sustainable farming system. Clearly, there is a minimum level of fertiliser and pesticide use required to sustain food crop production for a growing population. Even the most advanced integrated pest management practices today allow for some limited pesticide use. What is also important is that the pesticides that are used become less and less toxic and that we use less and less active ingredients per application. Nevertheless, it is an illusion and simply bad science to submit that sustainable crop production in the next century, which will meet food, fibre and chemical industry needs will be possible without recourse to chemical fertilisers and pesticides. Ecological agriculture with no, or minimal, external input will simply not be socially sustainable.

The demand for environmental protection is also income related and low-income countries will place a high priority on short-run investments to meet basic needs rather than on long-run investments focused on protection of the environment (Chapman and Barker, 1991). Thus, the demand for environmental protection is much higher in the industrialised countries than in the developing countries.

According to Norgaard, we do need to set aside more non-renewable resources for the future generations. This concerns in particular biodiversity, tropical rainforests and fragile ecosystems such as wetlands. Moreover, how much we need to set aside cannot be the subject of economic calculation, as it is simply an issue of intergenerational equity and political goodwill vis-à-vis the future generations.

One of the issues in this debate is, of course, the extent to which future technological breakthroughs will make the conservation of certain non-renewable resources (e.g. petroleum, coal, phosphate) redundant. This will concern the least biodiversity and probably most, if not all, non-renewable sources of energy. However, this is pure speculation. One

does have to realise that most chemical fertilisers are presently made largely from non-renewable resources: nitrogen fertilisers with natural gas as source of hydrogen in ammonia production, phosphates from phosphate rock and deposits and potassium from potassium mines. Luckily, phosphate and potassium natural resources are quite abundant and appear as inexhaustible today. Even for ammonia production, certainly other renewable sources for hydrogen, such as water, will be used some time in the future. However, probably no technology, not even biotechnology, will be able to replace lost plant and/or animal species. Jurassic Park is probably not of this world. Thus, biodiversity and nature conservation is of utmost importance for the future of mankind, as we cannot place a value on what species that are saved today may be worth several generations from now.

4. Conclusion

You will have noted that sustainability remains an ill-defined concept and that sustainability, as a concept, cannot be divorced from growth and development. In addition, the measurement of sustainability remains elusive and unsatisfactory. We content ourselves, when selected measures of sustainability move in the right direction, without worrying too much about the speed of the movement or the end goal that needs to be reached. Although sustainability is universal in its concept, it means different things to different people according to local circumstances and constraints. Here in South Africa, social sustainability is certainly stressed in a society in transition and the ecological sustainability will put emphasis on water resources and biodiversity. For South Africa, as in southern Europe or California or the Middle East, sustainable access to water is a major and growing concern. It thus appears that sustainability concerns focus on the resource that is most constraining, as in von Liebig's law of the minimum. It is probably appropriate to focus on those aspects of sustainability which are most constraining, without trying to encompass the full concept which remains elusive, as I have tried to show.

For all practical purposes, one also usually worries about the rights of only the next generation, our children so to say, hoping that technological development will help to alleviate the needs (e.g. for energy) of the more distant generations (our grandchildren). The exception to this is biodiversity, as what is lost in this generation will not ever come back, and may be invaluable. Moreover, Africa particularly, as the oldest continent, is so rich in biodiversity. For future food crop production, health and medicine preserving biodiversity may be the one area where Norgaard is probably right - we need to preserve as a right of future generations.

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ANNEX

DEFINITIONS OF SUSTAINABLE AGRICULTURE

*Sustainable agriculture (= S.A.) seeks to control technological inputs.

Directions for a sustainable agriculture include the following components:

1. Maximising opportunities for owner/operator farms.
2. Enhancement of the health of both farmers and consumers.
3. Enhancement of environmental quality: water, air.
4. Conservation of non-renewable resources: fossil fuels, soils, and genetic resources.
5. Maintenance of economic viability.
6. Broad public political control.
7. Co-ordination of all of these considerations.

This definition can be expanded further to include maintenance of healthy rural communities, development of healthy international relationships and consideration of "even the aesthetics of the countryside". (Flint *et al.*, 1989).

*S.A.: The appropriate use of crop and livestock systems and agricultural inputs supporting those activities which maintain economic and social viability while preserving the high productivity and quality of the land. (Flint *et al.*, 1989).

*S.A.: Low input agriculture: a set of agricultural production systems that seek to maintain productivity and preserve resources through the reduction or elimination of the use of pesticides and chemical fertilisers. (Corrigan, 1989).

*S.A. at the cropping level: the need to produce adequate output over time without irreparably damaging the natural resource base. (Spencer and Swift, 1992).

*S.D. is that which 'meets the needs and aspirations of the present without comprising the ability of future generations to meet their own needs'. (WCED, mentioned by Swift and Woomer, 1992).

*S.A. involves the successful management of resources for agriculture to satisfy human needs, while maintaining or enhancing the quality of the environment and conserving natural resources. (FAO, mentioned by Swift and Woomer, 1992).

*S.A.: Agricultural systems that are environmentally sound, profitable and productive and that maintain the social fabric of the rural community. (Keany, mentioned by Swift and Woomer, 1992).

*S.A.: A sustainable agricultural production system is defined as one which maintains an acceptable and increasing level of productivity, that satisfies prevailing needs and is continuously adapted to meet the future needs for increasing the carrying capacity of the resource base and other worthwhile human needs. (Okigbo, mentioned by Swift and Woomer, 1992).

*Sustainable land use is that which achieves production combined with conservation of the resource base on which that production depends, thereby permitting the maintenance of

productivity. (Young, mentioned by Swift and Woomer, 1992).

*Sustainability is the ability of a system to maintain productivity in spite of larger disturbances such as repeated stress or a major perturbation (for example, the building of soil salinity or a sudden outbreak of a new pest or disease). (Conway, mentioned by Swift and Woomer, 1992).

*A sustainable cropping system is one in which the output trend is non-declining and resistant, in terms of yield stability, to normal fluctuations of stress and disturbance. (Spencer and Swift, mentioned by Swift and Woomer, 1992).

*Duurzame landbouw is een vorm van landbouw waarbij enerzijds vernieuwbare hulpbronnen worden onderhouden, uitputbare grondstoffen met overleg worden gebruikt en natuur en milieu in waarde worden gelaten. Daarnaast dienen boeren een aanvaardbaar bestaan te kunnen opbouwen en dient tegemoet te worden gekomen aan de toenemende vraag naar landbouwprodukten. (de Wit, vermeld door Schakel, 1989).

*Duurzame landbouw is het beheer van agro-ecosystemen met het doel een toereikende en duurzame voorziening van de thuismarkt met voedsel- en andere natuurprodukten. Dit behoort te berusten op eerbied en verantwoordelijkheid voor en kennis van de biosfeer en te worden ondersteund door nationale en internationale wetten en overeenkomsten. (Vereijken, 1992).

*S.A. includes alternative, regenerative, low-input, ecological, environmentally sound, and even organic agriculture.

*There are different dimensions of S.A., important for both the developed and developing world:

- Time dimension: farmland preservation and soil conservation continues over centuries towards distant horizons.
- Social sustainability: the farm family and traditional rural community is believed to be able to endure over time, even with changes in the general farm economy.
- Economic sustainability: the farm unit is expected to remain economically viable in the long term; smallness and diversification are emphasised.
- Maintenance of soil and genetic resource bases: a diversified gene pool is a buffer necessary for long-term survival.
- Minimisation of environmental pollution: the changing human/land ratio means increasing demand for clean water and reduction of bio-pesticides in the environment.
- Lowered use of industrial inputs (fertiliser, pesticides, etc.): reduced agricultural chemical usage is needed to lessen adverse environmental impact and relieve demands on the fossil fuel resources.

To summarise: S.A. must make optimal use of the resources available to it to produce an adequate supply of goods at reasonable cost. It must meet certain social expectations, and it must not overly expend irreplaceable production resources. (Carter, 1988).

*S. A. allows people to make a living from a land without diminishing cycles that characterise it: nutrient and water cycles, disturbance and re-stabilisation cycles, predator and prey, symbiont and host, life and death relationships. Sustainability does allow impact and change. What it means is that the activities of humans become part of the cycles of a place in

a way that allows the whole system to continue to function and exist. Integrity is preserved. (Crouch, 1992).

*S.A. should

- Maintain the social structure.
- Enhance the quality of the environment (combat soil erosion, conserve groundwater, and avoid contamination).
- Reduce the dependence on non-renewable resources.
- Protect genetic diversity.
- Be economically viable. (NABC, 1991).

*S. A. should address the following needs:

Economic production:

- Improved commodity productivity for maintenance and growth of market share.
- Higher value in useable foods/feeds for increased profitability.
- New products for non-traditional expanded markets.

Resource preservation:

- Germ plasm, soil, water, fossil fuels, technology, bio-generated or recycled inputs, increased efficiency of use of non-renewable, land use.

Environmental neutrality to improvement:

- Global warming.
- Soil, water, toxic and undesirable residues.
- Soil, aquatic microbes.

Consumer:

- Food safety.
- Food healthfulness.
- Nutritional quality.
- Consumer preference.
- Ease/speed of preparation.
- Low cost.

Society:

- Zero to positive environmental input.
- No need to subsidise.
- Positive agricultural balance of payments.

S.A. may be high input, intermediate input, or low input but is not restricted to low input. (Hardy, 1989).

*Duurzame landbouw omvat volgende elementen:

- niet gebruik van synthetische chemicaliën zoals meststoffen en pesticiden.
- inputs verminderen om de kwaliteit van het milieu te bewaren.
- zich meer toeleggen op arbeid; dit houdt misschien een verminderde produktiviteit in en (niet noodzakelijk) een verminderde winst.
- behoud van familiebedrijven met hun verwachte landbouwpraktijken die regeneratie en geen lange termijn verliezen aan natuurlijke reserves teweegbrengen.
- evenwicht in het milieu met oog op lange termijn.
- milieukwaliteit verbeteren: bodemerosie, grondwatervervuiling, niet-hernieuwbare bronnen van energie, biologische diversiteit. (NABC Report 1, 1989).

*Aan de doelstelling van duurzame landbouw zijn twee aspecten verbonden, namelijk een milieu- en een sociaal-economisch aspect. Het milieu-aspect houdt in een duurzame instandhouding en ontwikkeling van het fysieke (produktie) milieu als natuurlijke hulpbron. Het sociaal-economisch aspect houdt in dat het landbouwbeleid een bijdrage verleent aan het bevorderen van een redelijke levensstandaard en maatschappelijk verantwoorde leef- en werkomstandigheden. (Ministerie van LNV, vermeld door NRLO, 1992).

*S.A. must make optimal use of the resources available to it to produce an adequate supply of goods at reasonable cost; it must meet certain social expectations, and it must not overly expend irreplaceable production resources. (Harwood, mentioned by Carter, 1988).

*Duurzame landbouw: beschermen van het eigen landbouwsysteem door de boer te wijzen op zijn "zorgplicht". Duurzame landbouw is een landbouw die de basismilieukwaliteit respecteert, d.w.z. landbouwproduktietechnieken welke blijvend kunnen worden ingezet zonder dat de basismilieukwaliteit in gevaar wordt gebracht, worden gestimuleerd. (Tijskens, 1991).