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SUSTAINABILITY

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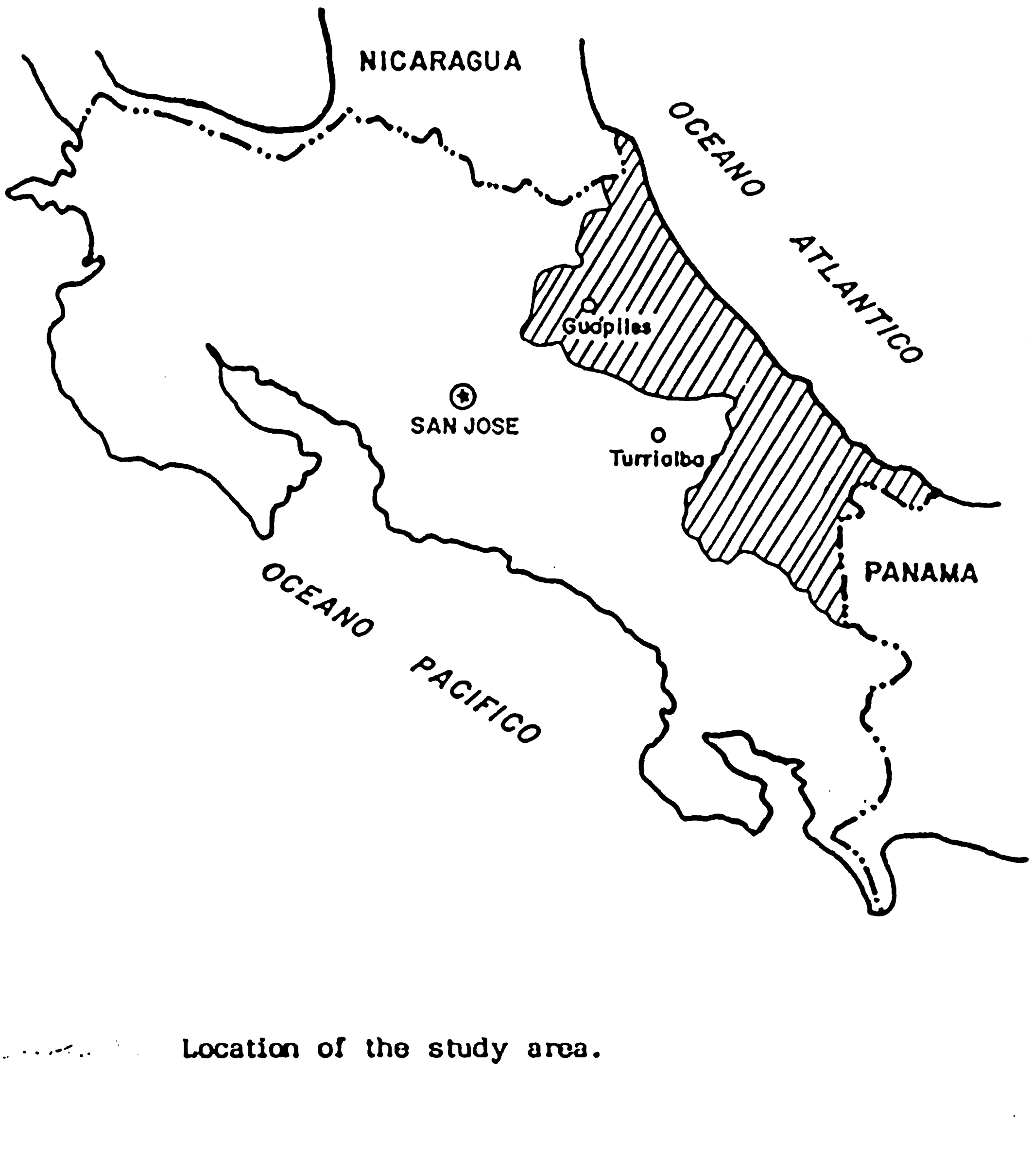

Location of the study area.

PREFACE

General description of the research programme on sustainable Landuse.

The research programme is based on the document "elaboration of the VF research programme in Costa Rica" prepared by the Working Group Costa Rica (WCR) in 1990. The document can be summarized as follows:
To develop a methodology to analyze ecologicaly sustainable and economically feasible land use, three hierarchical levels of analysis can be distinguished.
1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agroecological and socio-economic boundary conditions and the incentives presented by development oriented activities.

Ecological aspects of the analysis comprise comparison of the effects of different crops and production techniques on the soil as ecological resource. For this comparision the chemical and physical qualities of the soil are examined as well as the polution by agrochemicals. Evaluation of the groundwater condition is included in the ecological approach. Criterions for sustainability have a relative character. The question of what is in time a more sustainable land use will be answered on the three different levels for three major soil groups and nine important land use types.

Combinations of crops and soils

	Maiz	Yuca	Platano	Piña	Palmito	Pasto	Forestal I II III
Soil I	x	x	x		x	x	x
Soil II						x	x
Soil III	x			x	x	x	x

As landuse is realized in the socio-economic context of the farm or region, feasibility criterions at corresponding levels are to be taken in consideration. MGP models on farm scale and regional scale are developed to evaluate the different ecological criterions in economical terms or visa-versa.

Different scenarios will be tested in close cooperation with the counter parts.

The Atlantic Zone Programme (CATIE-AUW-MAG) is the result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Agricultural University Wageningen (AUW). The Netherlands and the Ministerio de Agricultura y Ganadería (MAG) of Costa Rica. The Programme, that was started in April 1986, has a long-term objective multidisciplinary research aimed at rational use of the natural resources in the Atlantic Zone of Costa Rica with emphasis on the small landowner.

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SUMMARY

The question dealt with in this publication is: what is sustainability? An attempt is made to find an answer to this question: first a review of opinions is given, and subsequently the problems involved in using the term are made clear for soil fertility and use of energy in four different agricultural systems.

Chapter 1 gives an introduction to the chapters 2, 3 and 4.

Chapter 2 gives the opinions and definitions of various authors with regard to sustainability in agriculture. Definitions range from very broad (including political aspects: the Brundtland-commission) to rather narrow (focussing on the farming systems level: Kotschi). A list of practices that are considered helpful in achieving sustainability at farm level is given. It is argued that the term 'sustainable' can at best be applied to certain components of a farming system. A sustainable farming system does not exist.

Chapter 3 deals with the components soil fertility and use of energy. The sustainability of these components is discussed for 'industrial farming' and 'ecological farming' in developed countries and for 'Green Revolution farming' and 'low external input farming' in developing countries. It is concluded that 'industrial farming' and 'Green Revolution farming' are sustainable for soil fertility, but only at farm level. 'Low external input farming' may at the moment be considered sustainable with regard to use of energy, but probably not in the future.

In chapter 4 the interrelation of soil fertility and use of energy is discussed. Compromises have to be made with regard to maintenance of soil fertility and sustainable use of energy, but what compromises? Other difficulties with regard to using the term 'sustainable' are the geographic scale and the time scale. Should sustainability be strived for at farm level or at global level? Should soil fertility or use of energy be maintained for the next 10 years or for the next 2000 years? It is concluded that man-made criteria determine if an agricultural system is called sustainable or not.

SAMENVATTING

Deze publicatie gaat in op de vraag: wat is duurzaamheid? Er wordt een poging gedaan om een antwoord op deze vraag te vinden: in de eerste plaats door een aantal meningen hierover op een rij te zetten, en vervolgens door de problemen te belichten die het gebruik van deze term oplevert met betrekking tot bodemvruchtbaarheid en gebruik van energie in vier verschillende landbouwsystemen.

Hoofdstuk 1 geeft een introductie op de hoofdstukken 2, 3 en 4.

Hoofdstuk 2 behandelt het begrip 'duurzaamheid'. De meningen en definities van verschillende auteurs met betrekking tot duurzaamheid worden gegeven. Deze definities variëren van erg breed (politieke aspekten inbegrepen: de Brundtland-commissie) tot vrij goed afgebakend (gericht op het landbouw-bedrijfssysteem: Kotschi). Een aantal technieken die van belang geacht worden voor het bereiken van duurzaamheid op bedrijfsniveau worden opgesomd. Er wordt beargumenteerd waarom de term 'duurzaam' hoogstens toegepast kan worden op bepaalde componenten van een landbouwbedrijf. Een duurzaam landbouwbedrijfssysteem bestaat niet.

In hoofdstuk 3 worden de componenten bodemvruchtbaarheid en gebruik van energie behandeld. De duurzaamheid van deze componenten wordt bediscussieerd voor 'geïndustrialiseerde landbouw' en 'ecologische landbouw' in het Westen, en voor 'Groene Revolutie landbouw' en 'lage investeringslandbouw' in ontwikkelingslanden. Er wordt geconcludeerd dat 'geïndustrialiseerde landbouw' en 'Groene Revolutie landbouw' duurzaam zijn wat betreft behoud van bodemvruchtbaarheid, maar alleen op bedrijfsnivo. Gebruik van energie in de 'lage investeringslandbouw' kan op dit moment als duurzaam beschouwd worden, maar waarschijnlijk niet in de toekomst.

Hoofdstuk 4 geeft een discussie over het verband tussen bodemvruchtbaarheid en gebruik van energie. Er moeten compromissen gemaakt worden wat betreft behoud van bodemvruchtbaarheid en duurzaam gebruik van energie, maar wat voor compromissen? Andere moeilijkheden wat betreft het gebruik van de term 'duurzaam' zijn de geografische schaal en de tijdsschaal. Moet er gestreefd worden naar duurzaamheid op bedrijfsnivo of op wereldschaal? Moeten bodemvruchtbaarheid en gebruik van energie gehandhaafd worden voor de komende 10 jaar of voor de komende 2000 jaar?
Er wordt geconcludeerd dat door de mens gestelde kriteria bepalen of een landbouwsysteem duurzaam genoemd wordt of niet.

PREFACE AND ACKNOWLEDGEMENTS

The idea for writing this literature review originates partly from my practical period, which I spent in Soconusco, a region in the state of Chiapas, Southern Mexico. In contrast with most other regions of the state of Chiapas, Soconusco is quite rich, and many farmers do have access to external inputs like fertilizers and pesticides. During contact with the researchers, one of the things that struck me was the benefit that most researchers seemed to expect from the use of these inputs. My knowledge about both sustainable development and ecological farming was quite superficial, but I wondered if, and how, ecological farming would be able to improve the situation of marginal farmers in that area. This problem appeared to be too complicated to deal with in a short study like this. The first obstacle encountered was: what is sustainable development? This question proved to be more than enough for a literature review.

I owe thanks to many people for helping me by giving their comments during the writing of this literature study. Especially I want to thank Theo Guiking for his enthusiastic and motivating supervision and for his many valuable suggestions.

1 INTRODUCTION

Sustainability is an ill-defined term used many times in literature on agricultural development. In this publication some of the definitions and concepts of sustainability encountered in the literature are listed and classified. Subsequently the problems involved in defining the concept of sustainability are clarified for two aspects of agriculture (soil fertility and use of energy). This was studied for four agricultural systems ('industrial farming', 'ecological farming', 'Green Revolution farming' and 'tropical low external input farming').

Most attention is directed towards 'Western ecological farming' and 'tropical low external input farming'. In both agricultural systems, sustainability is explicitly taken into consideration. Techniques used in both systems are strikingly similar in aspects as minimal use of pesticides and mineral fertilizers, multiple cropping, integration of both livestock and crop growing in the farming system, etc. In other aspects ecological farmers and tropical smallholders cannot be compared: the boundary conditions for ecological farmers in developed countries are such, that a high production is more easily achieved. Therefore, sustainable development of low external input agriculture in the tropics cannot be achieved by a direct application of 'sustainable' techniques from 'sustainable' Western ecological farming.

Chapter 2 gives a review of concepts of sustainability and of specific characteristics of sustainable agriculture. The results of this review are discussed.
Because the term 'sustainability' appears to comprise many interacting components, only two components (sustainable use of soil fertility and sustainable use of energy) are highlighted in chapter 3. The sustainability of these components is discussed for the four types of farming mentioned above, with special attention to Western ecological farming and tropical low external input farming.
Chapter 4 gives a discussion of the problems encountered when using the term sustainability, based on chapter 2 and chapter 3.

2 SUSTAINABILITY

2.1 Concepts of sustainability

Several concepts of sustainability exist in literature. Reviewed are the opinions of the Brundtland-commission, the FAO, an ad hoc committee of the NRLO (Dutch National Council for Agricultural Research), the views of some individual authors: Douglass, Gips, Conway and Marten, Lockeretz, Ruthenberg and the point of view of the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit, a German development organisation), as represented by Kotschi.

The opinions are classified hierarchically: the first definition is a general and rather political definition of sustainability given by the Brundtland-commission. Subsequently follow the definitions of the FAO, Douglass, Gips and the ad hoc committee of the NRLO. These definitions are narrower than the definition of the Brundtland-commission; they all focus on sustainable development and are restricted to agriculture. Finally the ideas of Conway, Marten, the GTZ, Lockeretz and Ruthenberg are given. The ideas of Conway and Marten focus on agroecosystems. Agroecosystems are not necessarily farming systems, but their definitions on sustainability are also useful at the farming systems level. The GTZ's ideas on sustainability are related to small scale farming systems. Lockeretz and Ruthenberg do not give definitions of sustainability, but mention characteristics or criteria for sustainable farming systems. Further comments will be given with the definitions.

A. WCED

The Brundtland-commission (World Commission on Environment and Development, WCED, 1987) gave the following definition on sustainable development:

> "Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations."

This definition is the most economic and most political one of the definitions presented here, as it was intended to cover any aspect of sustainability. Although the Brundtland-commission did not focus exclusively on agricultural production, the purport of this definition is similar to the one given by the FAO.

B. FAO

The definition that the FAO (1989) has formulated is the following:

> "Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for

present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors):
1. conserves land, water, plant and animal genetic resources,
2. is environmentally non-degrading,
3. technically appropriate,
4. economically viable and
5. socially acceptable."

The FAO-definition is meant as an unambiguous working definition to make long-term strategic and policy choices. In sustainable development, the FAO focuses primarily on the rural poor.

C. DOUGLASS

Douglass (1984) distinguishes three main approaches in the use of the term sustainability:

Sustainability as food sufficiency. In this approach world food sufficiency is the prime goal of agriculture. Followers of this view argue that with an increasing world population and a growing demand for food, the value of natural resources may end up to be less than the value of an increased food production. It is an economic approach, as it gives natural resources an economic value. According to Douglass, environmental costs like erosion and pollution are severely underestimated in this view. The use of low levels of external inputs is not necessarily implied. This view on sustainability focuses on productivity and is in contrast with the following two approaches presented by Douglass, and in contrast with the view that ecological farmers have on sustainability.

Sustainability as stewardship. This approach distinguishes non-renewable (e.g. fossil oil stocks) and renewable (e.g. croplands, grasslands, forests) natural resources. Important in this approach is the maintenance of productivity of renewable resources. It is acknowledged that inputs of non-renewable resources can increase agricultural productivity, but it is believed that large-scale use of non-renewable resources will eventually lead to a decreased productivity of renewable resources. This will happen because pollution will impair vitality of biological resources, and because an increase in population and consumption level cannot be sustained after the decline of non-renewable resources. Douglass calls this approach an ecological approach.

Sustainability as community. The followers of this approach agree with the preceding ecological view as well but they focus on community. In this approach it is stressed that man is embedded in relationships with other man and with nature. These relationships should be based on equity. Justice and participation in decision-making are considered very important. The relationship of man with nature should be based on respect, and not on domination. It may be called a social approach.

Douglass concludes that agricultural sustainability can be defined in many more ways. He believes that the three approaches should be integrated:

"agriculture will be found to be sustainable when ways are discovered to meet future demands for foodstuffs cheaply, safely, and equitably".

D. GIPS

Gips (1988) arrives at a similar integrated view on sustainability as Douglass (1984). Social as well as ecological and economic aspects are present. He considers agriculture sustainable if it is ecologically sound, economically viable, socially just and humane.

An agroecosystem that is ecologically sound is resource-efficient and assures the health of soil flora and fauna.

Economic viability means a positive net return or at least a balance in costs and returns. This is difficult to assess because some factors like family security and personal satisfaction are hard to quantify, and what is quantified depends on the values of the assessor.

Social justice is composed of two essential components: equitable control of resources and full participation. Equitable control means e.g. access to land, capital, technical assistance, etc. and full participation comprises e.g. the right to organize and democratic voting.

Humaneness includes values as the recognition of human dignity, respect for life and the protection of diverse cultures. Humaneness should not only be reflected in human interactions, but also in treatment of animals.

Gips stresses that sustainable agriculture is to be seen as dynamic.

E. NRLO - Ad hoc committee

An ad hoc committee on sustainable agricultural systems in the tropics was set up by the Nationale Raad voor Landbouwkundig Onderzoek (NRLO, Dutch National Council for Agricultural Research, 1990) for the draft of a three year vision on agricultural research 1991-1994.

According to this committee "sustainable agricultural systems in developing countries is a better definition than sustainable agricultural systems in the tropics", because agricultural systems are only partly defined by biophysical circumstances like climate; but technical, social, cultural, economical, juridical and political circumstances define the agricultural system as well.

It is possible to link the term 'sustainability' with each of these circumstances. To avoid ambiguity of the term 'sustainability', the committee distinguishes two categories: sustainability with regard to natural resources and sustainability with regard to human action. Natural resources may change slowly, and negative changes are mostly irreversible. Human action can be changed, perhaps slowly, but it is not irreversible. The committee therefore proposes to connect the term 'sustainability' only with natural resources. It defines sustainable agricultural systems as:

> "agricultural systems that do not deplete the potential productive capacity of the natural resources".

In addition to this definition, it is explicitly stated that social aspects should not be neglected. Social aspects, however, are better described with the term feasibility ('haalbaarheid').

The view of the committee is in contrast with the other views, as it believes the term 'sustainability' is best connected with natural resources only.

F. CONWAY and MARTEN

Conway and Marten are two individual authors. The theories developed by Conway (1985; 1987) were, amongst others, criticized by Marten (1988).

Conway (1985; 1987) looks upon sustainability as one of the properties of the agroecosystem. He defines an agroecosystem as an ecological system partly modified by man to produce food or other agricultural products. An agroecosystem has both biophysical and socio-economic boundaries. It does not have a specific size: a cropping system, a farming system and a village are all agroecosystems. An agroecosystem is an entity, like an organism. In his view an agroecosystem can be described by four interconnected properties: <u>productivity</u>, <u>stability</u>, <u>sustainability</u> and <u>equity</u>. The properties may be used as indicators of performance in agroecosystem analysis.

<u>Productivity</u> is the output of valued product per unit of resource input (figure 1). Later he adds (Conway, 1987) that this is not necessarily valued product in terms of kg harvest per unit of land or per unit of labour. Other things as psychological well-being or generation of employment are also valued products.

<u>Stability</u> is the constancy of productivity in response to small disturbances caused by normal fluctuations of the surrounding environment (figure 1).

<u>Sustainability</u> is the ability to maintain productivity in spite of major disturbances in the environment. Sustainability may be indicated by 1) resistance to stress or a shock, i.e. the ability to restore productivity after a decline (called resilience by Marten, 1988), and by 2) persistence of productivity by continuous stress (figure 1).

<u>Equitability</u> is the evenness of distribution of the production of the agroecosystem among the human beneficiaries (figure 1).

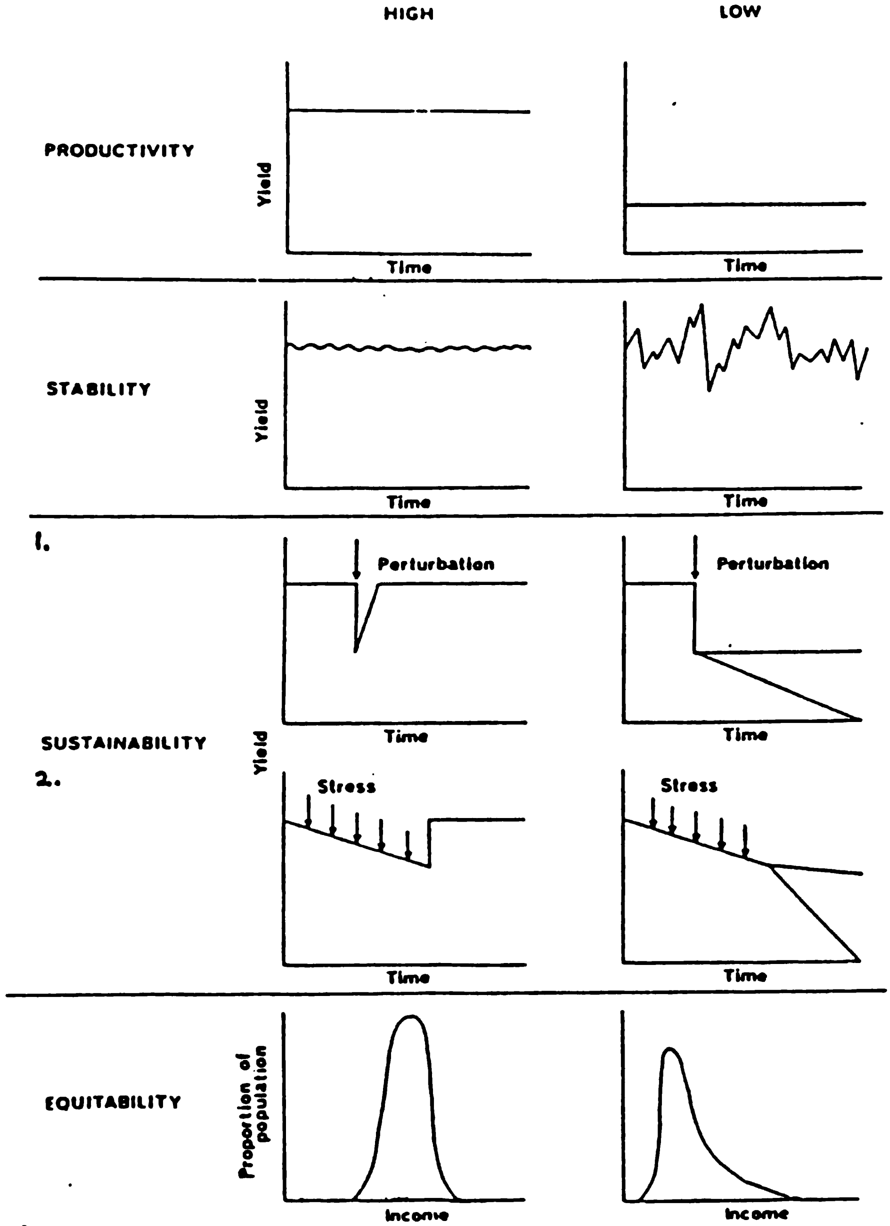

Figure 1 Schematic representation of agroecosystems that score high versus ones that score low on 4 properties as defined by Conway (1985).

Marten (1988) mentions additionally autonomy as a property of the agroecosystem. Autonomy is the self-sufficiency of the agro-ecosystem.

Marten (1988) stresses the multidimensionality of the properties of agro-ecosystems. This makes assessment of the properties of an agroecosystem very complex. In agroecosystem analysis, Marten (like Conway) assigns a central place to productivity. Productivity can be measured in kg/ha, kJ/labour unit, $output/$input or whatever. All outputs of an agroecosystem have their own unit of measurement. Productivity is thus multidimensional.

According to Conway, sustainability means: maintenance of the level of productivity. As productivity is multidimensional, an agroecosystem can be sustainable if yields in kg/ha are considered, but not sustainable if yields in kg/unit cost are considered, argues Marten. For example: if increasing fertilizer inputs are needed to maintain the production per hectare, yield in kg/ha may be sustainable, but yield in kg/unit cost is not.

Marten (1988) also introduces the concept 'resilience'. He defines this as the degree an agroecosystem can recover from external disturbances. Resilience is thus identical to Conway's first definition of sustainability (figure 1). Marten believes that resilience is intermediate to sustainability and stability. Stability and sustainability are not only connected properties, they also influence each other. For example: if knowledge about how to produce in extreme situations gets lost because of increased stability of production, increased stability can reduce resilience and therefore sustainability.

As Marten indicates, the multidimensionality could create much confusion. 'Productivity' will mostly be described in terms of monetary yield, food value or biomass production. Other 'products' as personal satisfaction may also be important. On the other hand: if a concession is made and yield gets a broader meaning ('generation of employment' or 'psychological well-being'), analysis becomes very complex. Furthermore, Conway argues that not everything needs to be known about an agroecosystem to produce a useful analysis. Given the multidimensionality of the properties chosen, it will be rather difficult to decide what needs to be known to call an agroecosystem 'stable' or 'sustainable'.

G. GTZ / KOTSCHI

The GTZ (Deutsche Gesellschaft für technische Zusammenarbeit) has published several publications that deal with sustainable farming systems in the tropics[1]. According to Kotschi et al.(1989), sustainable agriculture, environmentally sound agriculture, organic farming etc. all refer to forms of land use which depend primarily or almost exclusively on local resources to achieve lasting productivity. Site-appropriate agriculture (ecofarming) should be developed to achieve this. 'Site-appropriate' refers not only to ecological properties of the site, but also to social, cultural and economic characteristics of the inhabitants. Important in the development of site-appropriate systems is the emphasis on a closed system, diversity within the system and autonomy of the system.

The concept of sustainability of the GTZ may not seem as structured as the point of view of Conway and Marten. The GTZ does not primarily aim at analysis of the agroecosystem, but rather at development of the agroecosystem. Sustainability according to the GTZ is thus a characteristic of the agroecosystem as a whole, rather than a characteristic of a component. Given the complexity of farming systems one could wonder if sustainable farming systems do exist.

[1] Especially Kotschi has published much on this subject. It is not always clear whether the views are those of the GTZ or those of Kotschi.

H. LOCKERETZ

Lockeretz (1989) does not give a definition of sustainable agriculture. He states that:

> "sustainable agriculture is a loosely defined term for a range of strategies to cope with several agriculturally related problems causing increasing concern in the U.S. and around the world".

He mentions contamination, loss of soil and soil degradation, shortages of non-renewable resources and low farm incomes as 'agriculturally related problems'. Strategies to cope with these problems are related to the farm level. Examples of such strategies are: multiple cropping, minimizing losses of nutrients and integrated pest management.

Lockeretz's article is very much based on the situation in North-American agriculture.

I. RUTHENBERG

Ruthenberg (1980) proposes to use soil fertility as the major criterion for "maintenance of the farming system". Other possible criteria, such as yield levels, livestock numbers, farm capital, etc. are highly variable because of changes in prices, and are therefore unreliable yardsticks for measurement of maintenance of the farming system. Soil is available in given quantities only, and soil loss is often an irreversible process.

2.2. Elements of sustainable agriculture

Many authors link sustainable agriculture with specific techniques and cropping practices that enhance sustainability (Lockeretz, 1989; Kotschi et al, 1989; Zeelenberg, 1989; Masters, 1982; etc.). Characteristic elements of sustainability vary according to the definition of sustainability given and depend on hierarchical level and target group of the author. The aspects of sustainability at global level are entirely different from the aspects of sustainability at farm level. The Brundtland-commission considers e.g. awareness of political leaders for the implications of their decisions as an indispensable element for sustainable development (WCED, 1987). Political decisions seriously influence the decisions taken by the farmers. Stimulation of certain cash crops by the government may be beneficial for the country's economy, but detrimental with regard to soil conservation. Another example is clarification of land tenure matters. As long as insecurity of land tenure exists, farmers are not motivated to make any investment in practices that could enhance sustainability (Falloux, 1987).

At lower hierarchical levels biophysical factors become more important (NRLO, 1990). Manipulation of biophysical factors is possible at farm level. Various authors mention practices to be carried out at farm level. The practices mentioned for smallholders in tropical developing countries (Kotschi, 1989) are very similar to those mentioned for 'ecological' farmers in temperate Western countries (USDA, 1980; Lockeretz, 1989).

Elements of sustainability mentioned in literature are:
- diversity of crops: crop rotations, agroforestry, intercropping
- biological N-fixation: incorporation of legumes in crop rotation
- maintenance of protective soil cover: mulching, green manuring, reduced tillage
- minimization of nutrient losses: integrated animal husbandry, composting, mulching, green manuring, agroforestry
- integrated plant protection
- aquaculture
- contouring

Some elements are mentioned mainly for tropical areas like agroforestry and aquaculture.

2.3 Discussion

From the definitions given in § 2.1 follows that sustainability is a vague term. I believe that sustainability has many faces: one component[2] of a farming system could be sustainable (maintained at a desired level, also in the future) while another is not. If a farmer strives for sustainability of soil fertility, this will not necessarily mean that other components of the farming system become sustainable as well.

> For example: sustainability of soil fertility may compete with sustainability of returns for labour inputs. An increased input of labour (collecting organic wastes, making sure the soil is covered with crops all the time) may conserve and maintain soil fertility (make soil fertility sustainable), but this probably costs a lot of time and energy, which he could use more economically elsewhere. The farmer's returns for labour inputs decrease: returns for labour inputs are not sustainable.

In my opinion, there is no absolute sustainability of a farming system. Sustainability is something that can be strived for, but it is also something that is impossible to achieve for two reasons:

In the first place, the qualification 'sustainable' is not static: farming systems are dynamic and 'sustainability' is subject to changing criteria. Sustainability is a 'moving target'. This implies, that if a farming system is considered sustainable one day, it is not necessarily considered sustainable in the future.

Secondly, I believe that decisions made with regard to sustainability are in practice based on compromises between all components of a farming system. In most cases, the components of a farming system will achieve a certain degree of sustainability. The compromises that are made are situation-dependent. They depend on the situation of the farming system and on the personal priorities of the farmer.

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[2] Components of a farming system are (in this context) e.g. soil fertility, soil structure, availability of water, work load, security of production, etc. In other words: all elements that are influenced by the practices mentioned in § 2.1.

In the example mentioned above: farmers who consider sustainability of soil fertility very important will choose for high labour inputs to conserve soil fertility. Farmers who consider other work or leisure time more important, will accept a decline of soil fertility. A likely compromise is somewhat lower returns for labour together with a somewhat slower decline of soil fertility.

Thus, a sustainable farming system is at the best a set of components in which non-sustainability is avoided as much as possible.

3 SUSTAINABILITY OF TWO COMPONENTS IN FOUR FARMING SYSTEMS

In this chapter, the complexity of sustainability is illustrated with the components 'soil fertility' and 'use of energy'. These components are discussed for 'industrial farming', 'ecological farming', 'Green Revolution farming' and 'low external input farming' with special attention to 'ecological farming in Western countries' and 'low external input farming in developing countries'.

3.1 Justification and delimitation of concepts

Two components

Soil fertility and use of energy were chosen for the following reasons:

Decline of soil fertility is practically irreversible without considerable use of external inputs (Ruthenberg, 1980). Soil fertility is an important condition for productivity of farming systems. In literature on sustainability, at all hierarchical levels much attention is paid to conservation of soil fertility (e.g. WCED, 1987; Kotschi et al, 1989; Ruthenberg, 1980). Illustrative is the relatively high percentage of 'elements-of-sustainable-agriculture' (see § 2.2) that have an impact on soil fertility at farm level.

Use of energy and energy efficiency are major issues in political approaches of sustainability (e.g. WCED, 1987). Energy may come from non-renewable resources (e.g. oil, coal stocks) or from renewable resources (e.g. solar energy, wind energy and human and animal muscle power, plants, dung) (WCED, 1987). In the literature reviewed prudent use of energy at farm level receives little attention.

Four types of agriculture

The Brundtland-commission (WCED, 1987) distinguishes three types of agriculture:
- 'industrial' agriculture in developed countries
- 'green revolution' agriculture in developing countries
- 'resource-poor' (low external input) agriculture in developing countries.

As a fourth type of agriculture ecological farming in developed countries is added here.

Industrial agriculture refers to capital-intensive and usually large-scale farming, which is dominant in North-America, Western and Eastern Europe, Australia and New Zealand (WCED, 1987). This type of farming has been developed since the Industrial Revolution, and especially since the 1940's it has become very common (table 1).
In the countries mentioned above, other types than 'industrial' agriculture do exist. These types of farming are often lumped together as 'ecological', 'alternative' or 'organic' farming. Here it is further referred to as ecological farming[3]. Differences among

[3] The term ecological farming systems is in this publication only used to refer to farming systems in developed, temperate regions. In the strict sense of the word, many farming systems in developing tropical areas are also 'ecological'. This is not denied.

ecological farming systems are concerned with differences in accepted practices, different ideologies and different histories (Gips, 1988). This publication will not go further into these differences, but a glossary with main features of systems and terms used for these systems is given in the annex. As a group, they can be distinguished from the predominating way of farming by: the holistic approach, the preference for small-scale farming with a low level of external inputs and a high level of self-sufficiency, and by agricultural production with little or no use of agrochemicals (table 1).

Table 1 Four types of agriculture summarized.

	Industrial agriculture	Ecological agriculture	Green Revolution agriculture	Low external input agriculture
Main locations	industrial countries and specialized enclaves in developing countries	industrial countries	irrigated or stable rainfall resource-rich areas in developing countries	rainfed resource-poor areas in developing countries
Main climatic zone	temperate	temperate	tropical	tropical
Major type of farmer	highly capitalized family farms and plantations	large and small farmers	large and small farmers	small and poor farm households
Use of purchased inputs: N	very high	low	high	low/moderate
Use of purchased inputs: P	high	low/moderate	high/moderate	low
Use of purchased inputs: K	high	low/moderate	high/moderate	low
Use of purchased inputs: pesticides	high	low	high	low
Use of purchased inputs: machinery	high	high	high	very low
Labour demands	low	moderate	moderate/low	varying from low in shifting cultivation to high in permanent annual cropping
Access to information	very good	rather good	good	bad
Access to credit	good	good	rather good	bad
Energy efficiency	low	low	moderate	high

Source: modified after WCED (1987) and Chambers (1989).

<u>Green Revolution agriculture</u> refers to agriculture that is found in uniform, resource-rich, often flat and irrigated areas in the agricultural heartlands of some developing countries (WCED, 1987). Green Revolution farming exists since the development of high yielding varieties of wheat, rice and maize in the 1950's and 1960's (table 1).

<u>Low external input farming</u> (resource-poor farming) refers to all sorts of farming in tropical developing countries that rely on uncertain rainfall rather than irrigation, that is found in developing regions difficult to farm and with fragile soils: most of Sub-Saharan Africa and the more remote areas of Asia and Latin America (WCED, 1987). Low external input farmers hardly purchase any inputs and have little access to credit and external information (table 1).

Soil fertility and use of energy in ecological farming and in low external input farming

In ecological farming systems in developed countries, maintenance of soil fertility is one of the greatest concerns (Masters, 1982; Vereijken, 1989). In low external input systems in developing countries, increase and maintenance of soil fertility is of crucial importance. Especially in humid tropical areas low soil fertility is a principal problem (Webster & Wilson, 1980; MacArthur, 1980; Sanchez et al., cited in MacDicken, 1990). Ruthenberg (1980) even proposes to use soil fertility as the major criterion for "maintenance of the farming system".

In Western ecological farming systems more attention is paid to sustainability of soil fertility than to sustainability of use of energy. Sustainable use of energy, though acknowledged as important, does not seem to be a primary goal in ecological farming (COBL, 1977; Lockeretz, 1983). In low external input farming systems, formerly renewable forms of energy like firewood are no longer renewable as it is collected faster than it regrows. Energy efficiency is important in these systems, concludes the WCED (1987).

3.2 Sustainability of soil fertility

Maintenance of soil fertility is indispensable for maintenance of production (although soil fertility is not the only aspect of soil productivity).

To meet continuous and increasing demands on soil nutrients, the following options are possible:

- emphasis on supply of nutrients from outside the system: supply those nutrients that are removed with agricultural products. Nutrients may be added to the soil with artificial and organic fertilizers, and by biological N-fixation.
- emphasis on restriction of losses instead of supply of nutrients. This implies recycling of organic material (dung, crop residues), and cultivation of protective soil cover crops.

Especially the production of N-fertilizers still requires a lot of non-renewable energy (see § 3.3). Furthermore, excessive or thoughtless use of both artificial and organic fertilizers is a waste (leaching of N and K and even of P in P-saturated soils, NH3-volatilization, depletion of natural P and K resources) and causes eutrophy of surface waters.

Use of fertilizers has increased more in developing countries than in Western countries. Still the amount of N, P and K used in developing countries is a lot lower both per ha of agricultural area and per caput (table 2).

In industrial farming, decrease of soil fertility is usually compensated for by application of artificial fertilizers or liquid manure to the soil. Industrial farming is sustainable for soil fertility at farm level to this extent that industrial farmers are able to keep the amount of soil nutrients at the same level. However, the soil is overfertilized rather than underfertilized. Beyond farm level, the amount of artificial N-fertilizers used is not sustainable as long as the production of N-fertilizers requires so much non-renewable energy (see § 3.3). Excessive fertilization by liquid manure is possible because cheap concentrates are imported from developing countries, which leads to soil mining there. At a larger scale and for a longer period, industrial farming can not be considered sustainable.

Table 2. Consumption (in kg) per ha of agricultural area and per caput.

	Developed countries					Developing countries			
	kg nutrients per ha					kg nutrients per ha			
	1973	1978	1983	1988		1973	1978	1983	1988
N	14.2	17.4	19.8	20.7	N	4.3	7.6	10.8	14.4
P	4.6	5.1	5.1	5.2	P	0.9	1.2	1.7	2.4
K	7.5	8.8	9.0	8.9	K	0.6	1.0	1.2	1.9
	kg nutrients per caput					kg nutrients per caput			
	1973	1978	1983	1988		1973	1978	1983	1988
N	25.0	29.2	31.9	32.2	N	4.1	6.6	8.5	10.3
P	8.1	8.6	8.1	8.1	P	0.8	1.0	1.4	1.7
K	13.1	14.7	14.4	13.8	K	0.6	0.8	1.0	1.4

Source: FAO (1979; 1989)

Ecological farmers usually choose for recycling of nutrients rather than for supply of nutrients to maintain soil fertility. More than in industrial farming, the nutrient status is maintained by prevention of losses: integration of green manures, animal manure and crop residues (the latter two often composted). Sometimes 'natural' inorganic fertilizers are used (P, K). N-fixing crops are an important part of the crop rotation. Still, maintenance of soil fertility is one of the most crucial problems in ecological farming (Vereijken, 1989). According to Wagstaff (1987), most ecological farming systems tend to a slightly negative nutrient balance. Sometimes this is not perceived: to what extent soil mining takes place is hard to assess. Inputs of nutrients are very important for a balanced nutrient supply. Soil fertility at ecological farms seems to be sustainable to a higher extent than at industrial farms, because attention is paid to reduction of nutrient losses, nutrient recycling and restriction of use of artificial fertilizers. It should not be forgotten though, that ecological farms can rely on the relatively favourable situation that exists in Western countries:

- nutrient reserves are often high due to previous excessive fertilization
- they can rely on animal manure from industrial farms (and therefore on imported nutrients) if necessary
- information is relatively easily available
- soil analysis is carried out relatively often, which helps to prevent over- and underfertilization (Mela, 1988; Benecke et al., 1988; Van der Werff, 1989)
- mineral fertilizers are relatively cheap if there are problems.

In green revolution farming losses of soil fertility are usually compensated for with artificial fertilizers. Most of the N, P and K fertilizers in developing countries are consumed in green revolution farming. For green revolution farming the same is true as for industrial farming: green revolution farming is sustainable at the farm level in so far that losses of nutrients are sufficiently compensated for.

In tropical low external input agriculture, capital to purchase mineral fertilizers is not, or only to a low extent available. If mineral fertilizers are bought, mainly N-fertilizers are used. Application of organic fertilizers and restriction of nutrient losses is possible but in practice very difficult for small farmers for the following reasons:
Soil fertility problems in tropical climates are different from those in temperate regions. It should be taken into account, that in the humid tropics, much of the available nutrients are present in the above ground biomass. In temperate areas a relatively larger part is present underground. Chemical and biological processes occur more rapidly than in temperate areas because of higher temperatures. Organic material breaks down 2-3 times as fast as in temperate areas. For this reason, the emphasis lies on other conservation practices: more on agroforestry than on composting, for example. Furthermore, precipitation may be more sudden and heavy than in temperate areas and is often not well spread through the year. This means that in tropical soils nutrient losses through leaching and erosion are potentially more severe. In the humid tropics, another typical soil problem is the low pH of the soil (with high Al-activity and therefore P-fixation and Al-toxicity) (Webster & Wilson, 1980; MacArthur, 1980; Müller-Sämann, 1986). The use of organic fertilizers and of practices that restrict nutrient losses may be limited because of technical, social or economic constraints. An illustration: crop residues may be hard to integrate evenly into the soil if no machinery is available, animal manure is used for other purposes than fertilization (as fuel, for example) and integration of trees in the system does not give short term benefits: farmers in Rwanda for example did not adopt agroforestry practices because, among other things, returns for labour were paid back only after 10 years (Kotschi et al. 1989). The vulnerability of tropical low external input systems makes it very difficult to introduce any technique whatsoever, if it does not immediately improve the economic situation of the farmer. Often, immediate returns as a short term goal has more priority than sustainability as a long term goal. Low external input farming is usually not sustainable with regard to soil fertility. In the major part of Sub-Saharan Africa e.g. (with much low external input farming) nutrient losses are not sufficiently compensated for (Stoorvogel & Smaling, 1990).

3.3 Sustainability of use of energy

In all farming systems, energy is needed to produce agricultural products instead of spontaneously growing natural biomass (Pimentel & Pimentel, 1986; Jones, 1989).

Energy may be introduced in the agricultural ecosystem in many ways: as labour, as animal traction, as fertilizer, as herbicide, as fuel, etc. A distinction may be made between energy from renewable resources and energy from non-renewable resources (§ 3.1). In this publication energy that at the moment is generated by non-renewable resources is not considered sustainable (fuel, fertilizers, herbicides, etc.); energy generated by renewable resources (labour, animal traction, manures, firewood, etc.) is considered sustainable. It is admitted that this division is a bit diffuse: production of renewable resources of energy may be enhanced by energy from non-renewable resources (Douglass, 1984), and of course renewable sources of energy are only renewable if appeals made to them are not too heavy. For example, excessive cutting of firewood is not renewable. Non-renewable energy used for production of e.g. fertilizers could be renewable if the energy needed to produce them comes from inexhaustible natural resources (sun, water, wind).

The amount of non-renewable energy used in agriculture is low. Even in industrialized countries it is small compared to the amount of non-renewable energy used in other sectors (4-8 % of non-renewable energy consumption) (Pimentel & Pimentel, 1986; Le Pape & Mercier, 1983).

Machinery and mineral fertilizers (mainly nitrogenous fertilizers) are responsible for the major part of use of non-renewable energy in industrial agriculture in Western countries (62,1 and 35.5 % in 1982 resp.). Pesticides and irrigation account for a very small share (FAO, 1986) (figure 2). As long as energy inputs in industrial agriculture are based on non-renewable resources, industrial agriculture can not be considered sustainable with regard to use of energy.

In ecological agriculture use of non-renewable energy may be less than in industrial agriculture, because few or no inputs as mineral fertilizers and pesticides are used. The use of mineral fertilizers and pesticides is avoided by different management practices e.g. composting and crop rotations. In some cases (composting, which is labour intensive), a shift takes place from the use of non-renewable to renewable sources of energy. Ecological farming usually requires more labour inputs (Pimentel et al, 1983; Wagstaff, 1987). This problem is partly solved through longer working days or hired labour during labour peaks, but for a great deal the increased demand for labour is made up for by a more intensive use of machinery (examples in USDA, 1980; Masters, 1982; Wagstaff, 1987; Benecke et al., 1988; Zeelenberg, 1989; Vereijken, 1989). Weeding, for example is not carried out with herbicides but by hand and mechanically. Non-renewable energy saved by not using herbicides may be spent with the use of flame weeders and more weeding rounds by tractor. Fossil oil stock consumers as tractors and flame weeders are almost ubiquitous at ecological farms, and their use is often taken for granted. It may be doubted whether ecological farms could reach the productivity they have without mechanization.
The above leads to the conclusion that ecological farming does not necessarily lead to a lower use of non-renewable energy (Lockeretz, 1983; Pimentel et al, 1983; Wagstaff, 1987). Therefore, ecological farming systems are often not sustainable with regard to use of energy.

The situation for use of energy in developing countries is entirely different. The total amount of non-renewable energy used in agriculture is much smaller than in Western countries (FAO, 1986) (figure 2). A greater share of non-renewable energy is spent on fertilizers and a smaller share is spent on machinery. Most non-renewable energy consumption in developing countries takes place in green revolution agriculture. As long as energy consumption in green revolution agriculture is based on non-renewable energy, it can not be considered sustainable.

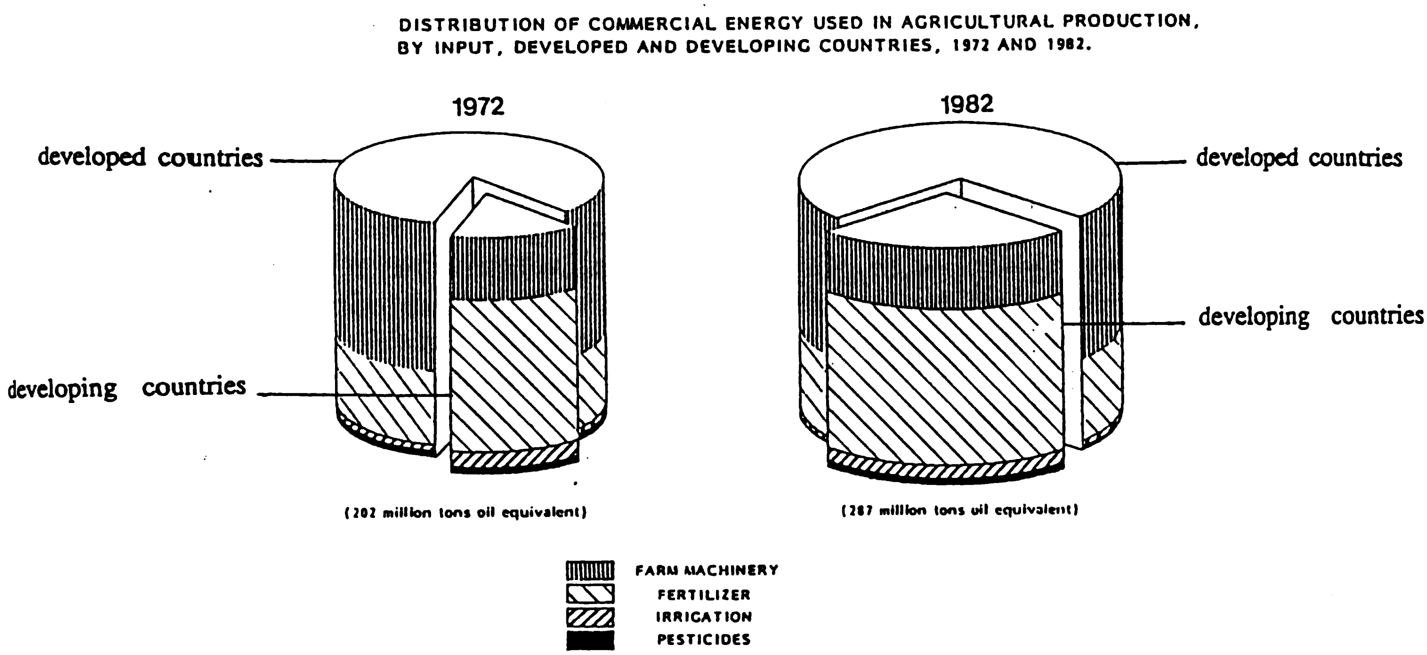

Figure 2 Distribution of commercial energy used in agricultural production, by input (FAO, 1986).

Farming practices in low external input agriculture are based on human and animal labour, metal and wood implements and limited use of modern inputs like chemical fertilizers and biocides (Le Pape & Mercier, 1983). In this type of agriculture, consumption of non-renewable energy is low. Non-renewable energy is mostly consumed as N-fertilizer. Till so far low external input systems may be considered sustainable. However, if agricultural production has to increase, increased use of energy inputs seems an obvious solution (Ruthenberg, 1980). For sustainable development, increased inputs of energy should not be based on non-renewable resources. Techniques involving solar, wind and water energy are hardly practised in tropical low external input farming. Anyway, increased use of external inputs is often not feasible. Therefore, increased use of energy will primarily be based on higher animal and human labour inputs. Decreasing energy returns for each unit of labour invested will finally become a problem. This makes energy efficiency important.

4 DISCUSSION AND CONCLUSION

Most components of farming systems are connected to each other. Also the components used in chapter 3 for illustration of the term sustainability, soil fertility and use of energy, are interconnected components. Conservation of soil fertility will influence use of energy: if people make heavy appeals to soil fertility and maintainance of soil fertility is important, increased energy inputs will be necessary to maintain production. On the other hand: sustainable use of energy (use of renewable energy) may imply, that a heavy appeal is made to soil fertility, e.g. when fuel is derived from wood and plants (firewood, alcoholic gasoline from sugar cane), or when animal traction is deployed instead of human labour (need for fodder). If a very heavy appeal is made to soil fertility, this sort of energy can not be called renewable any more. As already concluded in § 2.3, a sustainable farming system is at the best a set of components in which non-sustainability is avoided as much as possible. Because of interconnection of the components, striving for sustainability of some components may lead to a less favourable situation for other components of the farming system: compromises have to be made. But what compromises? For example in the case above: what is worse, unsustainable use of energy or unsustainable use of soil fertility?

Another difficulty in using the term sustainability follows from the examples in § 3.2: even if no artificial fertilizers are used, soil fertility may be sustainable at farm level or at a regional level, but in these cases other areas are likely to suffer through export of nutrients in products or in litter. At a global scale, nutrients may not be lost, but continuous removal of nutrients from the same place may locally lead to soils that are heavily eroded and impoverished. Such soils are hardly renewable at a reasonable term. Which geographic scale should be taken?

Not only the geographic scale, but also the time scale poses difficulties when using the term sustainability. In the first place because sustainability has to do with the future. May use of soil fertility be called sustainable if there is no decline in agricultural production for the next 10 years? Or can it only be called sustainable if there is no decline of production for the next 2000 years? In the second place difficulties arise because of the changing criteria mentioned in § 2.3: use of N-fertilizers may be called unsustainable now, because their production requires non-renewable energy, but is use of N-fertilizers still unsustainable if they are produced with renewable sources of energy?

The term 'sustainability' can not be used in an absolute sense. Man-made criteria for the various interrelated components determine to what extent an agricultural system is called sustainable.

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ANNEX <u>Glossary of 'ecological' farming systems</u>

Many 'ecological' farming systems are based on particular ideologies. These are important for understanding the system. Just an enumeration of farming practices does in some cases no justice to the farming system. For shortness, these ideologies are only briefly mentioned.

Alternative farming

Term used in industrialized countries to address farming systems that are an alternative to the prevailing, industrial type of farming. Alternative farming refers to any sort of farming that uses none or little mineral fertilizers and chemical pesticides. Often used as an equivalent to 'biological' farming, 'ecological' farming, 'organic' farming (definition 1), and 'sustainable farming (see below).

Biological farming

Term used for farming that is in accordance with natural laws of living systems. Often used as an equivalent to 'alternative' farming, 'ecological' farming or 'organic' farming (definition 1) (see above and below).

Biological-dynamic farming

Farming based on the antroposophic philosophy of Rudolf Steiner. Nature and farming systems are seen as an 'organic entities'. Soil is considered an 'organ' of nature. Nature is in a process of development, like biological oranisms. Cultivation of the soil opens it for other forces of nature like biotic and abiotic, but also cosmic forces. like those of the sun, the moon and the position of the planets. Fertilization supports and intensifies life processes of the soil, which optimizes plant growth. Plants are a 'bridge' between earthly and cosmic forces. Animals spread and distribute cosmic forces. As the farming system is an organic entity, a farming system that has closed material cycles is ideal. Farming practices: Fertilization: composting, animal manures, 'natural' mineral fertilizers, legumes. Crop rotation of 6 to 8 years with leys, no mixed cropping found by COBL. Use of 'preparations[4]' for growth-stimulation. Pests and diseases are controlled with 'preparations', and biological control agents. Weeding by hand or mechanically. Biological-dynamic farming is practiced all over Europe on a commercial scale. In the Netherlands in 1989, 224 of the 359 'alternative' farms were biological-dynamic (the remainder 'ecological') (COBL, 1977; Van Mansvelt, 1990; CBS, 1990).

Ecofarming

Term introduced by the GTZ; defined as 'sustainable farming with low levels of external inputs'. Important in ecofarming is adjustment of farming to both social and biophysical factors of the environment ('site-appropriate' farming; see below) (Kotschi <u>et al</u>., 1989).

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[4] 'Preparations' are solutions or powders composed of plant extracts, algae, trace elements, etc. They are applied to the crop, to the soil or to fertilizers for stimulating crop growth, for making up losses of certain elements, against pests and diseases, etc.

Ecological farming
Farming based on adjustment to principles and processes that govern the natural environment. More or less synonymous to 'alternative farming', 'biological farming' and 'organic farming' (definition 1) (see above and below).

Howard-Balfour method
Farming method developed by Sir Alfred Howard and Lady Eve Balfour according to their ideas with respect to composting, use of the mineral reserve in the subsoil and the role symbiotic mycorrhizae play in maintaining the health of the plant. Central in this type of farming is maintenance of soil fertility. Farming practices: Shallow tillage. Fertilization with compost, crop residues, 'natural' mineral fertilizers, legumes. Crop rotations 6-9 years, of which 3-4 years ley. No mixed cropping. Use of 'preparations' (see footnote 4). Control of pests and diseases by natural plant extracts, copper derivates (against phytophtera), sulfur, etc. Control of weeds by hand or mechanized, herbicides in special occasions. In England practised on a commercial scale (COBL, 1977; Van Mansvelt et al., 1990).

Lemaire-Boucher method
Farming method based on ideas of Kevran. Kevran states that the equilibrium in the soil is disturbed by mineral fertilizers, artificial pesticides and not-composted organic material. Composted organic fertilizers, legumes and the product 'Calmagol' (made out of algae, Lithothamnium calcareum), restore and maintain the equilibrium. 'Calmagol' induces biologic 'transmutations', which means that elements change into other elements, needed by the plant. Farming practices: Shallow tillage. Fertilization: compost (animal manure, crop residues and other compostable material), algae, legumes. Crop rotation of 7-8 years with leys, no mixed cropping. Use of 'preparations' (see footnote) as growth stimulants and for control of pests and diseases. Weeding by hand or mechanized. Practised on a commercial scale in Belgium and France (COBL, 1977).

Low input
Farming with reduced use of external inputs. In developed countries this refers mostly to reduced purchase of pesticides, fertilizers, farm equipment, etc. In developing countries this refers often also to little access to information and a low resource base (marginal cropping lands, debts, etc.).

Macro-biotic farming
1. Farming based on ideas of R. Kraft concerning 'multibipolair balance' in nature (see COBL, 1977). Farming practices: Superficial tillage. Fertilization with compost, liquid manure, 'natural' mineral fertilizer, legumes. Mulching important. Crop rotations with leys and mixed cropping. Use of 'preparations' in compost or on soil. No pest control; weed control through mulches or by hand. Practiced on a non-commercial scale in Europe.
2. Farming related to macro-biotic theories of nutrition. Developed by Kushi. No further information (COBL, 1977).

Mazdaznan method
Farming according to guidelines of Zarathustra and other Perzian prophets. Found in West-Germany on a very small and non-commercial scale. No further information (COBL, 1977).

Natural farming
1. Farming based on ideas of Fukuoka. Central in Fukuoka's ideas stands the conviction that unity should exist between man and nature. Then nature will respond by providing everything man needs. Natural farming is based on four principles: no cultivation, no chemical fertilizer or prepared compost, no weeding by tillage or herbicides and no dependence on chemicals. According to Fukuoka's 30-year experience rice yields of 6000 kg can be maintained with natural farming methods, without pest, disease and weed problems. Not practised on a commercial scale (Fukuoka, 1978; Van Mansvelt et al., 1990).
2. Sometimes the term is used for farming without artificial inputs. Then it is more or less synonymous to 'alternative' farming, 'biological' farming, 'ecological' farming or 'organic' farming (definition 1) (see above and below).

Organic farming
1. Term used in Anglophone literature for any sort of farming in which few or none artificial fertilizers and artificial pesticides are used. It should not be mistaken for organic-biologic farming. More or less synonymous to 'alternative', 'biological' and 'ecological' farming (see above).
2. Sometimes the term 'organic farming' is used to address the Howard-Balfour method.

Organic-biologic farming
Farming method based on theories of H.P. Rusch, and developed by H. and M. Müller. Important in this type of farming is the principle of life cycles (soil-plant-animal-soil or soil-plant-man-soil) in nature. Each part of the life cycle should be healthy. As in all life cycles lactic acid bacteria are present, they are chosen as an observation object to study parts of the life-cycle. Farming practices: Superficial tillage. Fertilization: no composts, only crop residues or fresh animal manures; 'natural' mineral fertilizers. Legumes. Mulching important. Crop rotations, sometimes with ley. No mixed cropping found. Use of 'preparations' (see footnote). Pests and diseases controlled by steaming of the soil, 'preparations', biological and some chemical pest control agents. Weeding by hand or mechanized. Practised on a commercial scale (COBL, 1977; Van Mansvelt et al., 1990).

Permaculture
Permaculture (permanent agriculture) is a collection of ideas invented by Bill Mollison. The ideas deal with ecological horticulture and agriculture, soil management and landscape, town and country planning. 'The philosophy behind permaculture is one of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless action; of looking at systems in all their functions, rather than asking only one yield of them; and of allowing systems to demonstrate their own evolutions'. Farming is based on 'biological' principles (see above). According to Mollison applicable everywhere if adjusted to local ecological environment (Mollison, 1988).

Regenerative farming
Farming that has the ability to recreate the resources that the system requires. More or less equivalent to 'alternative', 'biological' or 'ecological' farming or 'organic' farming (definition 1) (see above).

Site-appropriate farming
Term introduced by the GTZ ('standortgerechte Landwirtschaft') for farming adjusted to the social and biophysical environment of the farm and the farmer (Kotschi & Adelhelm, 1984). Literature on site-appropriate farming mostly refers to the tropics and subtropics.

Sustainable farming
Farming that has the ability to endure indefinitely (with continual adjustment to changes in environment).

Vegan farming
Farming according to vegan principles: only superficial tillage and no use of animal manures. Use of composted crop residues. Mulching important. Crop rotations and mixed cropping. Weeds are no problem (mulching). Use of 'preparations'. Only on a non-commercial scale (COBL, 1977).