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AGRICULTURAL SUSTAINABILITY:

Towards the Operational Definitions?

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ABSTRACT: This paper reveals the existing definitions and the extension of the concepts of sustainability. Despite the ambiguities of the term, the concepts of sustainability will remain useful for agricultural research and development. In practical terms, the longterm properties of agroecosystems; the internal sustainability and resilience, should be treated separately.Combining these two properties may lead to several difficulties in assessing agroecosystem performance. Various measurements may be easily found in the ecological studies but little attempts have been made in agroecosystem studies. The extension of sustainability concepts to social context of agroecosystems is found to be severely limited in the literature. Their contributions will be crucial for the future concerns of agricultural sustainability.

INTRODUCTION

It is generally accepted among the members of the Southeast Asian Universities Agroecosystem Network (SUAN) that sustainabiltiy is one of the distinct ecosystems properties and frequently relates to other properties such as productivity, stability and equitability (MCP,1980., KKU,1982., Sajise,1985., Conway,1985., Conway,1988 and Rerkasem and Rambo, 1988). Recently, additional properties; i.e., autonomy and solidarity, have been suggested and these properties have been introduced to the previous case studies workshop which was jointly organised by the Southeast AsianUniversities Agroecosystem Network and the Environment and Policy Institute of the East/West Center (Rambo and Marten,1986).

The idea of sustainability in agriculture is not new. For example the concept of sustained-yield which has been used since 18th century in forestry and later in fishery was extended to tropical agricultural systems (Janzen,1970.,Janzen,1972.,Janzen,1973., Wiebecke and Peter,1984). "Nachhaltigkeit" litterally refered as endurance, was fashionable in 1795 in Germany and originated from the concepts of "sustained" yields in forestry developed by von Carlowitz in 1713. However, the use of sustained-yield seems to be limited and probably remeins as theoretical basis for renewable resource management strategies. The term "sustainability" recently comes up on the scene and it is increasingly gaining popularity (Lowrance *et al.*, 1987).

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This paper attempts to review some of the concepts and definitions of sustainability as currently being applied to agriculture. It is hoped to encourage the discussions on the operational utility of the concept. No attempt will be made to identify a single definition for the future SUAN collaborative activities. It is still doubtful whether any single definition of sustainability can be agreed upon the individuals who are using the term.

DEFINITIONS, CONCEPTS AND AMBIGUITY

Various definitions of sustainability which currently appear in the literatures are compiled in Table 1. They may be of various meanings, i.e. ecological, agicultural, social, economic and institutional, and these create some confusions of the term.

Some thoughts have been given to the concepts of sustained-yield in relation to resource. In ecological term, maximum sustainable yield (MSY) of a natural resource is used to imply that a renewable resource such as fishery, forest, or field crops may be safely harvested up to a certain level (Clark and Munn, 1986., Munn,1988). As long as MSY is not exceeded, the resource is sustainable. It must be, however, emphasised that the yield of a renewable resource steadily increases up to the MSY (Figure 1), then suddenly drops sharply as the harvesting rate is above MSY (Walters, 1986). The concepts of sustainable yield has been successfully applied not only to biological resources such as harvesting rate in fisheries or extraction rate of timber in forestry, but also for stock of physical resources, such as underground water. Depletion of stock appears to be straight forwards, but extending the concept beyond biological or physical to include social parameters and using such terms as "sustainable development", have led to the ambiguity of the term (Dixon and Fallon,1988).

The term "sustainability" also remains ambiguous even in ecological literature. To begin with, the term sustainable is being used to mean "enduring" (i.e., lasting), "permanent", "durable" (i.e., ability to withstand, or bear up against), and "supportable" (i.e., able to be kept from falling) and many of these meanings have also been used interchangeably with the term "stability" (Marten,1986).

Another source of ambiguity is when ecosystem properties; i.e., stabitity and sustainability, are used to assess ecosystem performance; i.e. the interrelationships between the two properties. One ecosystem may be more stable or sustainable than another in some respects but less so in other respects (Figure 2). Recognising this ambiguity, Conway (1982), Conway (1984), Conway (1985), Conway (1986) and Conway (1987) suggested the assessment to be based on disturbances (Figure 3), where the lack of sustainability is due to the responses to disturbance; normally refers to stress or perturbation. We shall, however, see later that stress and perturbation may take enomous forms.

FIGURE 1 Schematic representation of the relation between rate of harvesting of a renewable resource and yield. (Munn 1988)

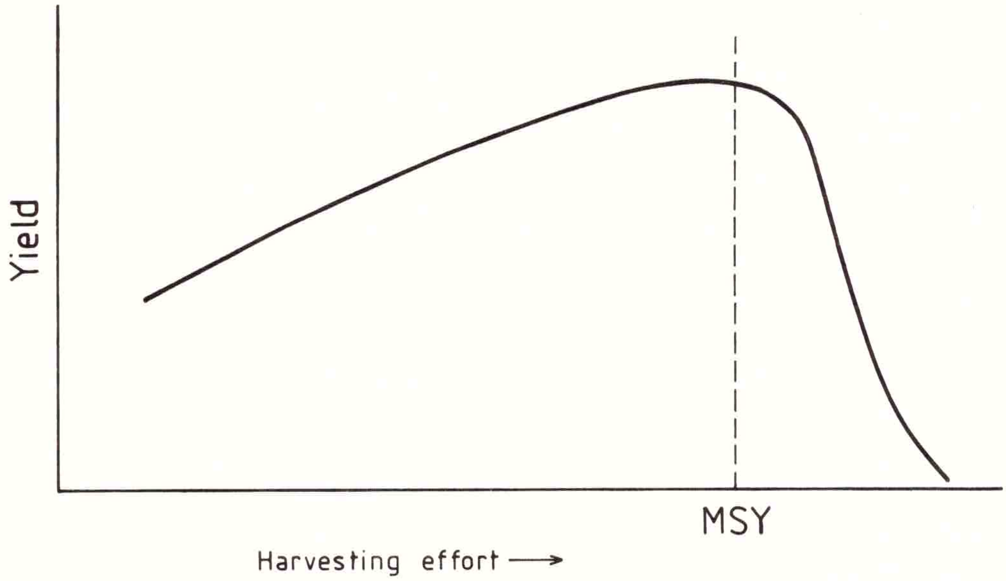
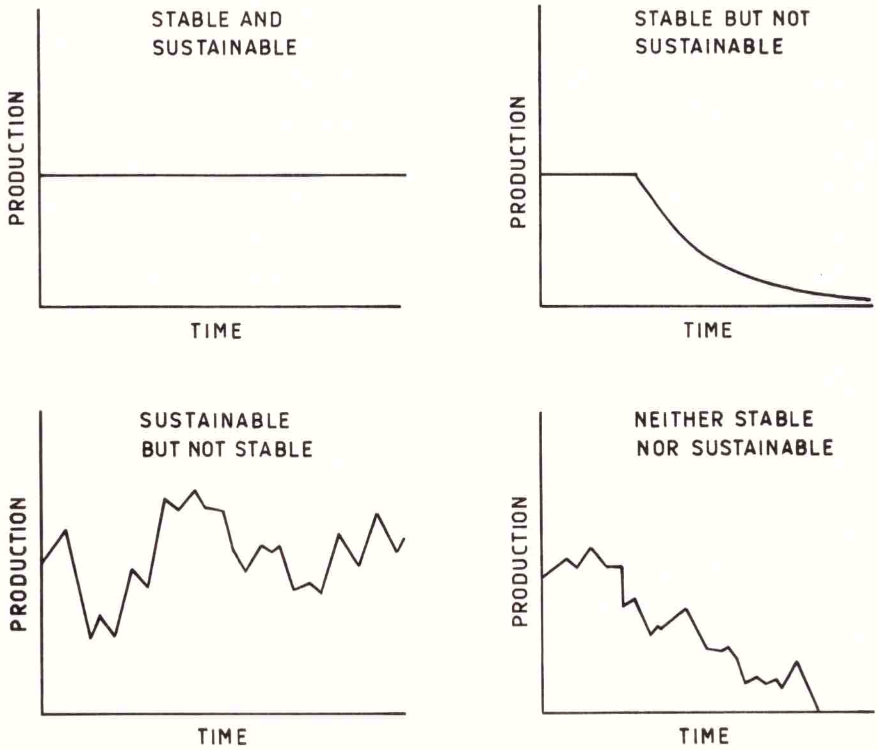


FIGURE 2 The meaning of stability and sustainability. (Craig et. al. 1980 and Marten 1988)



MEANINGS OF AGRICULTURAL SUSTAINABILITY

The idea of agricultural sustainability is currently popular among various people interested in alternative agriculture which attempts to minimize the potential negative effects of feeding growing populations. Wordings such as organic farming, regenerative agriculture, biodynamic farming, natural farming, biological farming and ecological farming are all included in the idea of alternative agricultural where the concepts of sustainability is tightly linked (Madden,1987., Altieri, 1983., Altieri, 1987., Gliessman, 1986 and Loomis, 1984). Traditional agriculture is another view which characterizes sustainable agriculture and contrast with the so-called contemporary (i.e. modern or conventional) agriculture. However, precise definitions of these terms are very few. Loomis (1984), for example, pointed out that the term "organic farming" embraces most none-conventional approaches, as well as those traditional in America before 1940. However, current definition of organic farming are generally based on the exclusion of manufactured chemicals; the use of natural phosphate and potassium ores are incidentally permited. In California legal definitions of organic farming may also allow the application of manures generated from chemically grown feeds or the use of lands that have been previously treated with chemicals.

The images of traditional agriculture are also embraced the idea of agricultural sustainability. According to Loomis (1984) the concepts rest in part on images of pioneers fulfilled, of peaceful fields in small farms, and of sage grandparents comfortable in their ability to produce from the land and to survive the vagaries of weather and markets. On the basis of variety of the meanings of the term, Douglass (1984) suggested three different views of agricultural sustainability. The first view -- sustainability as "food sufficiency" , seeks to maximize food production within constraints of profitability. The second view -- "sustainability as stewardship" was defined in terms of controlling environmental damage (Brown, 1984). The third view -- "sustainability as community" was defined in terms of maintaining and reconstructing rural value systems (Berry, 1984). Recently, Lowrance *et al.* (1987) suggested the integration of these concepts and proposed an alternative of a hierarchical approach. Because agricultural systems are simultaneously arranged in hierarchical orders, hance different constraints operate at different levels of organisation and that management strategies for sustainability must be considered and applied at appropriate levels. For practical Purposes, they defined agronomic sustainability for farm system, ecological sustainability for watershed or landscape system and macroeconomic sustainability for national or regional system (Table 1).

In reality, however, there exists the interactions between different levels in the hierarchy and that sustainability has to be evaluated at different levels of the hierarchy. According to Allen and Starr (1982) and O'Neill *et al.* (1986) a disturbance at one level in the hierarchy may be a stabilizing force at another. Hence, cotton production in Thailand tends to be stabilized at the regional level while the production

FIGURE 3 Stability and sustainability of agroecosystems.

Source : Conway (1982, 1986)

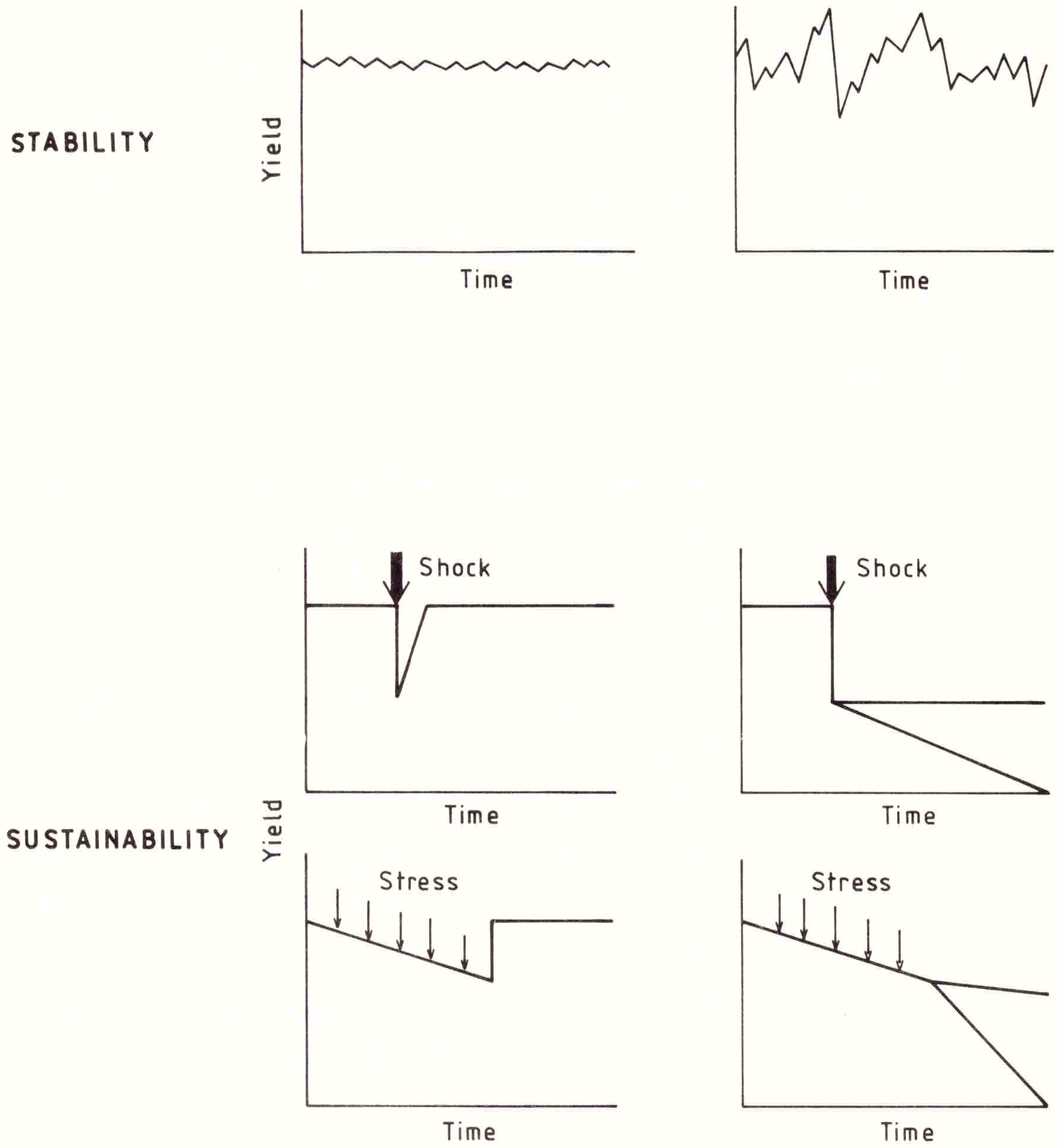


TABLE 1. Definitions of sustainability.

Source	Date	Definition
ECOLOGICAL:		
Canway	1987a,b	the ability of an agroecosystem to maintain productivity when subject to a major disturbing force; shock or stress.
Lowrance et al.	1986	the maintenance of life-support capacity of larger scale landscape units over longer time scale which is provided by non-agricultural and non-industrial segments of a region.
AGRICULTURAL:		
ASA	1989	sustainable agriculture is one that, over the long term, enhances environmental quality and the resource base on which agriculture depends; provide for basic human food and fiber neeeds, is economically viable, and enhances the quality of life for farmers and society as a whole.
BIFAD	1988	the successful management of resources for agriculture to satisfy changing human neедds while maintaining or enhancing the natural resource base and avoiding environmental degradation.
		the ability of an agricultural system to maintain production over time, in the face of ecological difficulties and social and economic pressures.
		should conserve and protect natural resources and allow for long-term economic growth by managing all exploited resources for sustainable yields.
Idachba	1987	refers to the ability of agricultural systems to keep production and distribution going continuously without falling. (In Davis and Schirmer 1987)

TABLE 1. (Cont.) Definitions of sustainability.

Source	Date	Definition
Lowrance et al.	1986	refers to the ability of a tract of land to maintain productivity over a long period of time.
Crosson	1986	defines a sustainable system of food production as one which sastifies demands for food into the indefinite future while meeting equity conditions in food production both within and across generations. By this definition, the systems which consistently fail to meet the equity criteria will be judged unsustainable.
Douglass	1984	sustainable agriculture seeks to maximize food production within constraints of profitability.
Brown	1984	the maintenance of yield capacity of renewable agricultural resources thus controlling environmental damage.
Altieri et al	1983	is long term stabilization which requires a simple modification of traditional ad hoc techniques to develop self-sufficient, diversified, economically viable and small scale agroecosystems. The requirements of sustainable agroecosystems clearly are not only biological or technical, but are also social, economic, and political and illustrate the requirements of a sustainable society. The final requirement for ecological agriculture is an attitude toward nature of coexistence, not of exploitation.
Douglass	1984	redefined as any combination of circumstances which permits farmers to meet future demands for foodstuffs without imposing on society real increases in the social costs of production and without causing the distribution of opportunities or income to worsen.
ECONOMIC:		
Lowrance et al.	1987	ability of a system to shift productivity among tracts of lands which is represented by the "farm"

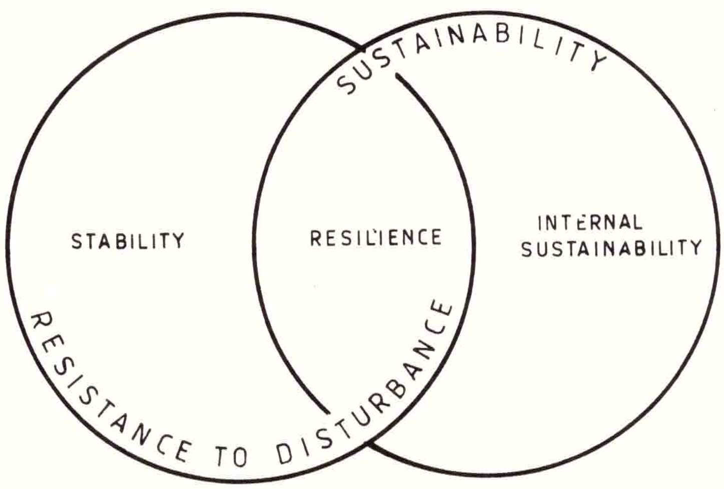
TABLE 1. (Cont.) Definitions of sustainability.

Source	Date	Definition
		The farm is the basic econmomic unit in the hierachy of agricultural systems where agronomic and economic factors are interacting to determine its sustainability. This also refers to microeconomic sustainability which is dependent on ability of the farm to stay on business. At the macro level, the (macro) economic sustainability is controlled by factors which determine the viability of national agricultural systems, e.g. fiscal policy and interest rates.
The Brundtland commission	1987	sustainable development is defined as develop ment that meets the needs without compromising the ability of future generations to meet their needs. (WCED, 1987 and Munn, 1988)
Pearce et.al.	1987	sustainable economic development involves maximising the net benefits of economic development, subjecting to maintaining the services and quality of natural resources over time.
Repetto	1987	refers sustainable development to the inter temporal conditions for continuing economic growth, and directs attention to the asset base-- particularly, to the natural resource asset base. (In Davis and Schirmer, 1987)
Gordon	1981	sustainable growth refers to short - term cyclical fluctuation and is often described as the desirable objective of macroeconomic demand management police. (seen in Cleveland, 1981)
SOCIOECONOMIC:		
Brown et al.	1987	defined global sustainability as one in which humans can survive without jeopardizing the continued suvival of future generation
Winkelman	1987	relates to causing to continue, maintaining at length without interruption, weakening, or lose of power or quality.

TABLE 1. (Cont.) Definitions of sustainability.

Source	Date	Definition
Fujisaka	1985	assessed sustainability in terms of potentials of the changing ecosystem and social system to support--over the long run--the activities and demands corresponding to given strategies.
Berry	1984	maintaining and reconstructing rural value systmens.
INSTITUTIONAL:		
Cernea	1984	defines project sustainability, essentially on economic terms, as the maintenance of an acceptable net flow of benefits from the project's investments after its completion, i.e., after the project ceased to receive financial and technical support. However, sustainable agricultural development, sustainable projects and investment programmes are not just those likely to generate an acceptable net flow of benefits, but are those which incorporate the establishment and/or strenghtening of the institutional and organizational sturctures that will endure as capable frameworks for the economic and technological processes promoted throung financially induced plan development.

FIGURE 4 Relationships of stability, resilence and sustainability. (Marten 1988)



systems at the field levels are fluctuating enormously due to pests and pesticide resistence problems. Field survey in the lower northern region of Thailand have shown that there has been a shift in production are from Sukhothai to Phetchabun, Nakhon Sawan and Kamphaeng Phet respectively (CMU/ CUSRI, 1983).

This hierachical approach to agricultural sustainability has been the focus of the SUAN memberships to evaluate systems properties of the tropical agroecosystems in Southeast Asia (e.g. Chareonwatana and Rambo,1988).

THE EVOLUTION OF THE DEFINITIONS OF SUSTAINABILITY IN SUAN

The concept of sustainability in SUAN was introduced in the late 1970s as one of the criteria to evaluate cropping system performance (MCP, 1980). The term "durability" was initially proposed and defined broadly as a measure of the long term productivity of the system (MCP, 1980 and Craig *et al.,* 1981). For multiple cropping systems, the term was used to designate the property of, or action on, any crop which affects the productive potential for the following crops.

The concept of durability was subsequently redefined as the long run performance of the system and measures how well the system is able to sustain its productivity in the face of repeated stress and/or major perturbation (Conway, 1982a). This definition has been widely adopted and refered as sustainability (Conway, 1982b., Conway 1985., KKU, 1982a., KKU1982 b., KEPAS, 1984., KEPAS, 1985a., KEPAS, 1985 b, KEPAS, 1986., KEPAS, 1988., PESAM/BRBDP , 1986 and Conway *et al.,* 1985). According to Conway (1987) the most recent definition of sustainability is refered to the ability of an agroecosystem to maintain productivity when subject to a major disturbing force. The actual or potential disturbance may be caused by an entensive stress, where stress is defined as a frequent, sometimes continous, relatively small and predictable disturbancd force which had a large cumulative effect (Figure 3). Alternatively, a disturbance may be caused by a shock, being defined here as an infrequent, relatively large and unpredictable disturbing force which has a potential of creating an immediate, large disturbancd or perturbation.

To appreciate the dynamic properties of disturbances, one may simply think in terms of time pattern as frequent or occasional; Periodic or irregular and sudden or cumulative. Recognising these patterns, farmers are uaually prepared for frequent disturbances, and hence stable response of agroecosystems, e.g., double transplanting of rice in the flash flooded areas of Chiang Mai and Chiang Rai provinces of northern Thailand (Rerkasem,1980); manipulation of rice varieties to overcome labour shortage, deep water zones and suboptimal planting time in multiple cropping systems (Rerkasem and Rerkasem, 1984) and diversity of economic activities of farmers in the northeast of Thailand to cope with natural variation and economic uncertainty (Grandstaff, 1988). Response to disturbance could take many different forms, Producing two distinct agroecosystem roperties; sustainability and resilience.

SUSTAINABILITY AND RESILIENCE

It may be seen that Conway's definition of sustainability combines the concept of resilience which was originally proposed by Holling (1973). This concept of resilience was derived from the concepts of ecological stability (e.g., Brookhaven symposium in Biology, 1969., van Dobben and Lowe-McConnell,1985) and refers to the ability of an ecosystem to adapt to a continuously changing environment, being able to absorb external shocks without major structural damage. If stability is defined as fluctuations on productivity that result from numerous fluctuations in physical and social variations of agroecosystem and sustainabiliby refers to a given level of productivity that can be maintain over time, then resilience may be seen as the intermediate between stability and internal sustainability as shown in figure 4 (Marten,1986., Marten, 1988a., Marten, 1988b).

The internal processes of ecosystem sustainability may be ecolological or social that cumulatively undermine agroecosystem productivity, e.g. soil degradation, increasing dependency on pesticides as pests develop increasing resistence. On the other hand as agroecosystem fails to produce satisfactorily under the impact of external disturbances, e.g. severe drought, pesticide-resistence of new biotype, increasing cost of inputs and collapse of an export market, the system may shift to a completely different state. This is termed resilience. In short, resilience concerns the response of production to external desturbance; like stability, and at the same time it concerns the maintenance of production; like sustainability. Unlike stability, resilience deals with whether the agroecosystem can persist in the face of disturbances which are occasional but traumatic,while stability concerns routine fluctuations in response to frequent and generally tolerable disturbances.

SUSTAINABILITY AS OPERATIONAL CONCEPTS

So far, we have seen many meanings of sustainability -- enduring or lasting, permanent or durable (i.e., ability to withstand, or bear up against), and supportable (i.e., able to be kept from falling). Some has suggested sustainability as part of stability and that sustainability is separated from resilience. There is a need, however, to recognize that a lack of sustainability is a response to disturbance and this is sometimes refered to perturbation or stress. (Conway, 1985., Conway, 1986).

Patterns of Disturbance and Perturbation

First of all, disturbances take an immensely variety of forms. Each form may also differ radically with regard to its impacts and vary considerably from one agroecosystem to the others. Second, an agroecosystem's response to disturbance can take a variety of forms. According to Trenbath (1982) perturbation can be due to both exogenous and endogenous and may be classified according to the nature of the main underlying mechanisms which include physical, chemical, biological, social, economic and technology. Example of these events and processes causing changes in agricultural systems are listed in Tables 2. An alternative approach to classify perturbation may be thought in terms of time-courses. The first source of perturbation, a pulse or "spike"-type stimulus is where a driving variable external to the system shows an abrupt but short-lived extreme deviation from its normal distribution of values (Figure 5a). Other kinds of stimulus include"step" changes where the value of the driving variable shifts abruptly to a new maintained level., "ramp" changes where there is a sustained trend over a significant period, and regular and random fluctuations that either begin or end (Figure 5a).

The responses to these stimuli can be categorised correspondingly, and slightly extended to include another three different types, i.e., step with overshoot return, step with damped return and assymptotic step (Figure 5a,b). Putting together in Table 3, Trenbath (1982) found that (1) only abrupt stimuli (i.e., spikes and steps) can have spike response, (2) all stimulus types can have responses of the same type, and (3) strongly lagged responses and overshoots are possible but seem not very common. In separating two different sources of perturbations, the exogenous degradation is often abrupt while endogenous degradation is gradual. Hence, the definitions of resilience and internal sustainability are once again treated separately.

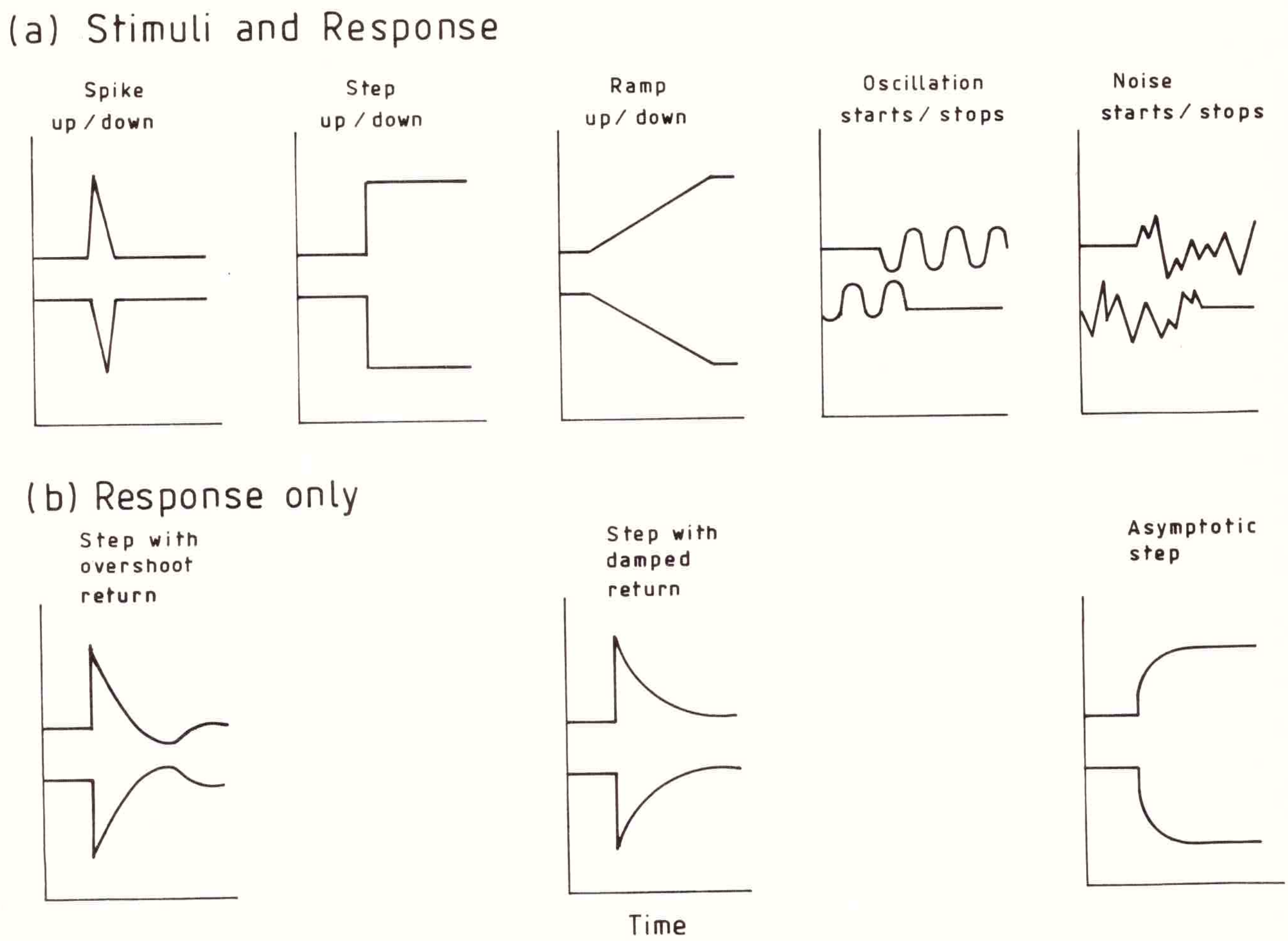
Measurements of Sustainability

Five characteristics have been suggested for measuring sustainability of ecosystems (Orians, 1975., Westman, 1978). These include inertia, elasticity, amplitude, hayteresis and malleability (Table 4). With exception to inertia which is the measure of resistence to change, the others are properties of resilience which refers to ways in which the disturbed system responds.

One may adopt the concept of LD_{50} from bioassay to measure the damage that causes 50% change in the composition. The relative abundance of species measured as percentage of similarity index (Whittaker, 1975) may be applied to agricultural systems, e.g., tropical homegarden (Ambar *et al.*, 1988). Elasticity or restoration time is the time required to restore a particular charateristic of an agroecosystem to within acceptably close limits of its pre-impact level, e.g., regeneration time of forests (Cairns, 1980 ., Bormann and Liken,1981) or recovery rate of disturbed agroecosystems, say restoring periods of soil fertility in shifting cultivation (Nye and Greenland,1960), and recovery time after pest-damage and so on.

The measures of amplitude (brittleness) involve determining a threshold, if any, beyond which ecosystem repair to the initial state no longer occurs. Pasture agronomists are interested in determining the stocking rate to maintain a given composition of the sward indefinitely, Minimum length of fallow period in shifting cultivation to maintain acceptable yields is another example of the measure of amplitude.

FIGURE 5 Common types of dynamic behaviour of variable involved in perturbation of agricultural systems. (Trenbath 1982).



Hysteresis refers to the degree to which the pattern of recovery is not simply a reversal of the pattern of initial alteration. It is the measure of ecosystem subjected to chronic impact, in which the changes induce in the ecosystem occur over a sufficient length of time that sequence can be observed. In crop-livestock systems, secondary succession may be observed after removal of livestocks. Shifts in weed species after removal of control measures and/or alteration of cropping strategies is another example of differences in paths of alteration and recovery. Malleability refers to the ease with which the system can become permanently altered. The measurement of malleability involves determining the similarity of the new stable state to former one.

These characteristics of sustainability are not equally easy in terms of measurements. Some have shown to be unmeasurable either in a short time or poor historical data. This, perhaps, exphasises the need for the sort of longterm perturbation experiment or on-farm monitoring whereby recovery of agroecosystems can be assessed.

TABLE 2. Exogenous (environmental) and endogenous events and processes that cause changes in agricultural systems.

Nature of Mechanism	Events and Processes	
	Exogenous	Endogenous
Physical	Drought, flood, rainstorm, hail, frost, decomposition of volcanic ash, landslide	Waterlogging due to blocking of drainage systems, soil erosion
Chemical	Volcanic and / or industrial missions (e.g., SO_2), chemical contamination and warfare	Nutrient depletion, declining yields or soil pH, loss of O.M.under intensive cultivation, laterisation
Biological	pest and disease outbreak e.g., locusts or blight	Building up of weeds, resistence to pesticide or herbicide, breaking resistent crop varieties
Social	Births, deaths and illness in the farm family, callup to army, change in social status	Departure of members in the family, e.g., marry,
Economic	Price fluctuation;produces and inputs, government subsidies, taxations	Various forms of mismanagement, e.g., over spraying
Technological	Introduction of farm machineries, new varieties or new breed, new pesticides or fertilizers	Varietal selection by farmers, increasing cropping intensity

Source : Trenbath (1982)

TABLE 4. Characteristics of sustainability/resilience and example of a physical system.

Characteristic	Definition	Example: a metal coil
Inertia	Resistence to change.	Force needed to stretch coil a given distance.
Elasticity	Rapidity of restoration of a stable state following disturbance.	Time required to spring back to initial size after streching a given distance.
Amplitude	Zone from which the system will return to a stable state.	Distance beyond which coil cannot be stretched without being permanently deformed.
Hysteresis	Degree to which the path of restoration is an exact reversal of path of degra-dation.	Degree to which region temporarily occupied by coil in springing back differs from region through which coil moved during stretching.
Malleability	Degree to which stable state established after disturbance differs from the original steady state.	Degree to which stretched coil remains stetched after deforming force is remo-ved.

Sources: Orian (1975) and Westman (1978)

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TABLE 3 Examples of stimulus-response combinations classified according to the time relationships of the stimulus and response involved. Refer to Figure for the types of time relationship. (Trenbath , 1982)

STIMULUS TYPE	RESPONSE TYPE							
	Spike	Step	Ramp	Damped return	Overshot return	Step without return	Oscillations stop/start	Noise stops/starts
Spike	Wind storm temporarily closes stomates	Rain storm erodes soil exposing unproductive rock	Establishment of trash bunds leads to terace formation and gradually decreasing runoff	Rain shower in arid zone produces short-lived burst of grass growth	Flood reduces pasture growth this year but silt depostied enhances growth in next year	Intenes erosion leaves so little soil that slow erosion continues till rock is reached		
Step	Law changes, and farmers organise one-day strike that halts market deliveries for a day	Rise of water level following breaching of dike stops crop growth	Farmer dies and farm productivity shows steady decline	Faced with great pest problems, farmer renounces pesticide, suffers temporary great loss, but lishes alternative controls		Irrigation introduced gives immediate yield rise which continues to plateau as utilisation skill increases		
Ramp		Falling price for product finally forces farmer to abandon farm and migrate to city	As product price rises percentage of area planted to it increases					
Oscillations start/stop		Notion starts summer daylight saving so farmer, unable to face rise in labour costs of summer milking, sells cows	Regular use of erosion-control measures started and leads to progressive rise in residue production, rainfall infiltration and yields	Watermanagement works lead to regular flooding. All farmers leave but as adaptation possibilities are recognised, families gradually return			Water management works lead to regular flodd-ing. Farmers continue crop-ping but plant only at the end of a flood	
Noise starts/stops		New smelter emission causes crop damage in direction depending on wind. In nearby farms, cultivation of suscep tible crop ceases in the next season	Destruction of flood defences lead to irregular flooding and progressive depauperisation of farmers as consecutive crops fail	Product price becomes unstable and so progressively less of this crop is grown.				Irregular peaks in product price attract opportunist producers able to set up fast, temporarily exploit the high price and then switch as price falls

REFERENCES

Ambar, S., Ruchiyat, Y. and Iskandar, J. (1987). Rural system interactions: Impact of land use change and deforestation on the environment in Phu Wiang watershed. In: SUAN/KKU report on Ecosystems Interactions in Rural Landscape: The case of Phu Wigng watershed, northeastern Thailand". Pp.53-104. Khon Kaen University, Thailand.

Allen, T.F.H. and Starr, T.B. (1982). Hierarchy: perspectives for ecological complexity. Chicago: University of Chicago Press.

Altieri, M.A. (1983). Agroecology: the scientefic basis of alternative agriculture. Berkley: UCB.

Altieri, M.A., Letourneau, D.K. and Davies, J.R. (1983). Developing sustainable agroecosystems. BioScience 33: 45-49.

ASA (1989). Decision reached on sustainable ag. Agron. News (January 1989): 15.

Berry, W. (1984). The agricultural crisis as a crisis of community. In: G.K. Douglass (ed) Agricultural sustainability in a changing world order. Pp. 140-158. Colorado: Westview Press.

BIFAD/AID (1988). Environment and natural resources: strategies for sustainable agriculture. A task force report of the Board for International Development, Washington, D.C.

Brookhaven symposium in Biology (1969). Diversity and stability in ecological systems. Brookhaven National Laboratory, Department of Biology. New York.

Brown Jr., G.E. (1984). Stewardship in agriculture, Pp.147-158 In: G.K. Douglass (ed) Agricultural sustainability in a changing world order. Colorado: Westview.

Brown, B.J., Hanson, M.E., Liverman, D.M. and Merideth Jr., R.W. (1987). Global sustainability: toward definition. Environ. Manage. 11: 713-719.

Bormann, F.H. and Likens, G.E. (1981). Pattern and process in a forested ecosystem. New York: Springer -Verlag. 253 pp.

Cairns Jr,J. (1980). The recovery process in damaged ecosystems. Michigan: Ann Arber Science. 167 pp.

Charoenwatana, T. and Rambo, A.T. (1988). Sustainable rural development in asia. Proceedings of the 4th SUAN regional symposium on Agroecosystem Research. Khon Kaen, Thailand.

Cernea, M.M. (1987). Farmer organisations and institutional building for sustainable development. Regional Development Dialogue 8: 1-24.

Clark, W.C. and Munn, R.E. (1986). Sustainable development of the biosphere. Cambridge: Cambridge University Press.

Clawson, M. and Sedjo, R. (1984). History of sustained-yield concept and its application to developing countries. In: K.H. Steen (ed) History of Sustained-Yield Forestry: A Symposium. Pp.3-15. FSH/IUFRO.

Cleveland, H. (1981). The management of sustainable growth. Pergamon Press. 395 pp.

CMU/CUSRI (1983). Agricultural development project in lower northern Thailand.

Report submitted to the National Economic and Social Development Borad (NESDB). Chiangmai University and Chulalongkorn University Social Research Institute. May 1983.

Conway, G.R. (1982). Applying ecology. Inaugural lecture 7. December 1982. London: ICCET.

Conway, G.R. (1985). Agricultural ecology and farming systems research. In: J. Remenyi (ed) Agricultural Systems Research for the Third World Agriculture. Canaberra: ACIAR.

Conway, G.R. (1986). Agroecosystem research and development. Bangkok: Winrock International. 111 pp.

Conway, G.R. (1987a). The properties of agroecosystems. Agric. Syst. 24: 95-117

Conway, G.R. (1987b). Sustainable agroecosystem development for Thailand. A report prepared for the United States Agency for International Development, Bangkok. Washington, London and Buenos: International Institute for Enveronment and Development IIED). 88 pp.

Conway, G.R., Alam, Z., Husain, T. and Mian, M.A. (1985). An agroecosystem analysis for the northern areas of Pakistan. Gilgit, Pakistan, Aga Khan Rural Support Programme.

Craig, I.A., Gypmantasiri, P., Rerkasem, K., Rerkasem, B., Jaisa-ard, R., Ganjanapan, L. and Thani, P. (1980). Multiple cropping in the Chiangmai valley: the complex relationships between components in the multiple cropping system. Multiple Cropping Project, Chiangmai Uniersity. Thailand.

Crosson, P.R. (1986). Sustainable food production: interactions among natural resources, technology and institutions. Food Policy (May 1986): 143-152.

Davies, T.J. and Schirmer, I.A. (1987). Sustainable issues in agricultural development. Proceedings of the 7 th Agricultural Sector Symposium. The World Bank. Washington, D.C.

Dixon, J.A. and Fallon, L.A. (1988). The concepts of sustainability: origins, extensions, and usefulness for policy. In: EAPI/RSI-EWC week: Resource/Environment - perspectives on critical issues. 27-29 September 1988, East-West Center, Honolulu.

van Dobben, W.H. and Lowe-McConnell, R.H. (1985). Unifying concepts in ecology. The Hague: Dr. W. Junk Publishers. 302 pp.

Douglass, G.K. (1984). Agricultural sustainability in a changing world order. Colorado: Westview.

Fujisaka, S. (1985). Agroecosystems co-evolution and sustainability in five pioneer upland shifting cultivation communities in the Philippines. EAPI/EWC Draft Paper. 45 pp.

Gliessman, S.R. (1984). Resource management in traditional tropical agroecosystems in southeast Mexico. In: G.K. Douglass (ed) Agricultural sustainability in a changing World order. Pp. 191-201. Colorado: Westview press.

Grandstaff, T.B. (1988). Environment and economic diversity in Northeast Thailand. In: T. Charoenwatana and A.T. Rambo (eds) Sustainable Rural Development in Asia. Pp 11-22. Proc. SUAN-4 regional symposium on agroecosystem research. Khon Kaen: Farming Systems Research Project and Southeast Asian Universities Agroecosystem Network.

Holling, C.S. (1973). Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. 4:1-23

Holling, C.S. (1978). Adaptive environmental assessment and management. New York: Willey International.

Idachaba, F.S. (1987) Sustainability issues in agricultural development. Pp.18-51. In: T.J. Davies and I.S. Schirmer (eds) Sustainable issues in agricultural development. Proc. 7 th Agricultural Sector Symposium. Washington: The World Bank.

Janzen, D.H. (1970). The unexploited tropics. Bull. Ecol. Soc. Amer. 51 : 4-7.

Janzen, D.H. (1972). The uncertain future of the tropics. Nat. His. 8: 80-89.

Janzen, D.H. (1973). Tropical agroecosystems. Science 182: 1212-1219.

KEPAS (1984). The sustainability of agricultural intensification in Indonesia. Jakarta, Kilompok Penelitian Agor-ekosistem, Agency for Agricultural Research and Development (AARD). Pp.1-115.

KEPAS (1985a). The critical uplands of Eastern Java: an ago-ecosystems analysis. Jakarta, Kelompok Penelitian Agro-ekosistem, Agency for Agricultural Reserach and Development (AARD). Pp.1-213.

KEPAS (1985b). Tidal swamp agro-ecosystems of Southern Kalimantan. Jakarta, Kelompok Penelitian Agro-ekosistem, Agency for Agricultural Research and Development (AARD). Pp.1-146.

KEPAS (1986). Agro-ekosistem daeraj kering di Nusa Tengara Timur: studi kasus enam desa pengambangan pertanian. Kelompok Penelitian Agro-ekosistem, Badan Litbang Pertanian.

KEPAS (1988). Pendekatan agroekosistem pala pola pertanian lahan kering: Hasil penelitian di empat zone agroekosistem Jawa Timuor. Kelompok Penelitian Agroekosistem, Agency for Agricultural Research and Development (AARD).

Loomis, R.H. (1984). Traditional agriculture in America. Ann. Rev. Ecol. Syst. 15: 449-478.

Lowrance, R, Hendris, P.F. and Odum, E.P. (1987) A hierachical approach to sustainable agriculture. Amer, J. Alter. Agric. 1: 169-173.

Madden, P. (1987). Can sustainable agriculture be profitable? Environment 29: 19-34.

Marten, G.G. (1986). Productivity, efficiency, stability and sustainability as properties for agroecosystem assessment. Paper presented to the SUAN/EAPI workshop on Agroecosystem Analysis. 6-10 January 1986. Khon Kaen, Thailand.

Marten, G.G. (1988). Productivity, stability. sustainability, equitability and autonomy as properties for agroecosystem assessment. Agric. Syst. 26: 291-316.

MCP (1980). An interdesciplinary perspective of cropping systems in the Chiangmai valley: Key questions for research. Multiple Cropping Project, Chiangmai University, Thailand.

Munn, R.E. (1988). Towards sustainable development: an environmental perspective. Paper presented at the International Conference on Environment and Development. 24-26 March 1988. Milano, Italy.

Nye, P.H. and Greenland, D.J. (1960). The soil under shifting cultivation. Tech. Comm. 51, Commonewalth Bureau of Soils. Harpenden. 156 pp.

O'Niell, R.V., DeAngelis, D.L., Waide, J.B. and Allen, T.F.H. (1986). A hierarchical concept of ecosystems. Monographs in Popolation Biology 23. Princeton: Princeton University Press.

Orians, G.H. (1975). Diversity, stability and maturity in natural ecosystems. In: W.H. van Dobben and R.H. Lowe-McConnell (eds) Unifying concepts in Ecology. Pp. 139-150. The Hague: Junk.

PESAM/BRBDP (1986). The agroecosystems of Buhi: problems and opportunities. Proceedings of the Buhi Agroecosystems Analysis Workshop. Program on Environmental Science and Management, UPLB and the Bicol River Basin Development Program. 14 - 18 November 1985, Naga city, Philippines. 279 pp.

Rambo, A.T. and Sajise, P.E. (1984). An introduction to human ecology research on agricultural systems in southeast asia. Los Banos : UPLB.

Repetto, R. (1987). Managing natural resources for sustainability. Pp.167-179. In: T.J. Davies and I.A. Schirmer (eds) Sustainability issues in agricultural development. Proc. 7 th Agriculture Sector Symposium. Washignton: The World Bank.

Rerkasem, K. (1980). The rice systems. Paper prepared for the regional workshop on Interdisciplinary Analysis of Resource Ecosystems. 9-13 December 1980. Multiple Cropping Project, Chiang Mai, Thailand.

Rerkasem, B. and Rekasem K. (1984). The agroecological niche and farmer selection of rice varieties in the Chiangmai valley, Thailand. In: A.T. Rambo and P.E. Sajise (eds) An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia. Pp.303-311. Los Banos: UPLB, Philippines.

Rerkasem, K. and Rambo, A.T. (1988). Agroecosystem research for rural development. proceedings of the 3rd SUAN regional symposium on Agroecosystem Research. Chiang Mai, Thailand.

Trenbath, B.R. (1982). A framework for the study of the dynamics of agricultural systems. In: G. Golubev and I. Shvytov (eds) Modeling agricultural environmental Processes in crop production. p.227-254. Proceedings of a 2-4 June 1980 Task Force Meeting. Laxemburg: II ASA.

Walters, C. (1986). Adaptive mangement of renewable resources. London: MacMillan. 374 pp.

WCED (1987) Our common future. Oxford: Oxford University Press. 383 pp.

Westman, W.E. (1978). Measuring the inertia and resilience of ecosystems. BioScience 28: 705-710.

Wiebecke, C. and Peter, W. (1984). Aspects of sustained-yield history: forest sustention as the principle of forestry -- Idea and reality. In: H.K. Steen (ed) History of Sustained-Yield Forestry: A symposium. Pp.176-182. FHS/IUFRO.