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title:	Indicators of Land Quality and Sustainable Land Management : An Annotated Bibliography Environmentally and Socially Sustainable Development Series. Rural Development
author:	Dumanski, J.; Gameda, S.; Pieri, Christian J. M. G.
publisher:	World Bank
isbn10 | asin:	0821342088
print isbn13:	9780821342084
ebook isbn13:	9780585183152
language:	English
subject	Land capability for agriculture--Evaluation--Bibliography, Land use, Rural--Evaluation--Bibliography, Agricultural ecology--Bibliography, Environmental indicators--Bibliography.
publication date:	1998
lcc:	Z5074.L27D85 1998eb
ddc:	016.33376
subject:	Land capability for agriculture--Evaluation--Bibliography, Land use, Rural--Evaluation--Bibliography, Agricultural ecology--Bibliography, Environmental indicators--Bibliography.

Indicators of Land Quality and Sustainable Land Management

An Annotated Bibliography

A joint publication of the World Bank and Agriculture and Agri-Food Canada

ENVIRONMENTALLY AND SOCIALLY SUSTAINABLE DEVELOPMENT
Rural Development

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The World Bank
Washington, D.C.

Manufactured in the United States of America
First printing March 1998

Cover image: Landsat 5 image, island of Seram, Maluku Province, Indonesia (path 108/row 62, May 7, 1997). Prepared by Petter Nyborg, Geographic Information Systems (GIS), Environment Family, World Bank.

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Library of Congress Cataloging-in-Publication Data

Dumanski, J.
Indicators of land quality and sustainable land management: an
annotated bibliography / Julian Dumanski, Samuel Gameda, and
Christian Pieri.
P. cm. (Environmentally and socially sustainable
development series. Rural development)
ISBN 0-8213-4208-8
1. Land capability for agriculture Evaluation Bibliography.
2. Land use, Rural Evaluation Bibliography. 3. Agricultural
ecology Bibliography. 4. Environmental indicators Bibliography.
I. Gameda, S. II. Pieri, Christian J.M.G. III. Title.
IV. Series.
Z5074.L27085 1998
[S591]
016.33376 dc21 98-14345
CIP

The text and the cover are printed on recycled paper, with a flood aqueous coating on the cover.

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Foreword

In 1997 the United Nations General Assembly held a special session on the global environment, Rio+5. During this session a set of priority actions was announced by the World Bank Group, including increased activities on issues such as desertification and land degradation, which are to be delivered through a revitalized rural strategy. Some key components of this new strategy are sustainable agricultural development, conservation of natural resources, and promotion of sustainable land management, including the development of indicators and procedures for monitoring the impacts of rural development policies and programs on the productivity and quality of land resources (World Bank, 1997).

This bibliography is an important building block for global and national programs on sustainable land management. Since the 1992 Rio Earth Summit (UNCED), there have been innumerable attempts to develop indicators, a virtual "indicator factory," but with little or no coordination. Starting in 1992, Agriculture and Agri-Food Canada, along with the International Board for Soil Research and Management (IBSRAM), the U.N. Food and Agriculture Organization (FAO), and the International Society of Soil Science, began to develop the concept of sustainable land management. In 1995 the World Bank Group established a global coalition with the U.N. Environment Programme (UNEP), U.N. Development Programme (UNDP), FAO, and Consultative Group on International Agricultural Research (CGIAR) to develop and test indicators of land quality. These institutions took the lead in producing this annotated bibliography, which assembles and organizes the available scientific information on indicators of land quality and sustainable land management to make these data more user-friendly and accessible to those who need it. These indicators are intended to help monitor whether human interventions in the landscape are leading toward or away from sustainability.

This bibliography includes selected publications and reports from the international literature, as well as some of the most useful URL sites on the World Wide Web (WWW). It represents a considerable volume of work, but much remains to be done. On behalf of our partners, I invite others to contribute their knowledge and experience and to join this initiative to develop improved indicators and procedures for monitoring and evaluating sustainable land management.

ISMAIL SERAGELDIN
VICE PRESIDENT
ENVIRONMENTALLY AND SOCIALLY
SUSTAINABLE DEVELOPMENT NETWORK

Acknowledgments

The authors and sponsoring agencies for this volume would like to gratefully acknowledge the contributions made by others toward the publication process. Both the International Development Research Center (IDRC) and the International Board for Soil Research and Management (IBSRAM) collaborated in this effort and supported the work of Brenda Heald in compiling some of the original annotations. During the project Julian Dumanski was partly supported by the Danish Trust Funds, in cooperation with John Dixon of the Environmentally and Socially Sustainable Development Network of the World Bank Group. The report was reviewed by D. F. Acton, G. Roloff, and Valerie Kirkwood of Agriculture and Agri-Food Canada, and Paul O'Connell and David Gray of the World Bank. Word processing was done by Sarian Akibo-Betts. Entry of the document on the WWW and hyperlinking it with other source documents in the 'Land and Water Knowledge Management Node' was achieved by staff from the Consortium for International Earth Science Network (CIESIN). Alison Raphael copyedited the volume, with editorial contributions by Alicia Hetzner and Virginia Hitchcock. The report was desktopped by Gaudencio Dizon.

Abbreviations and Acronyms

AAFC	Agriculture and Agri-Food Canada
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AEI	Agri-environmental indicator
AEZ	Agro-ecological zoning
CAPPA	Computerized system for agricultural and population planning assistance
CATI	Computer-assisted telephone interviewing
CCD	Convention to Combat Desertification
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centre Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIESIN	Consortium for International Earth Science Interaction Network
CIFOR	Center for International Forestry Research
CIMMYT	Centro Intenacional de Mejoramiento de Maiz y Trigo
CIRAN	Center for International Research and Advisory Networks
CSD	Commission for Sustainable Development
DDBS	Development data bases service
DSR	Driving force-state-response
ENTRI	Environmental treaties and resource indicators
EPI	Environmental performance indicators
ERDC	Electronic Research Database Committee
FAO	Food and Agriculture Organization of the United Nations
FESLM	Framework for evaluation of sustainable land management
FMU	Forest management unit
GDP	Gross domestic product
GHG	Greenhouse gas
GTOS	Global Terrestrial Observation System
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
GWP	Global warming potentials
IAC	International Agricultural Center
IAM	Integrated assessment modeling
IBSRAM	International Board for Soil Research and Management
ICLARM	International Center for Living Aquatic Resources Management
IDIC	International Development Information Center

IDRC	International Development Research Center
IDRIS	Inter-agency Development Research Information System
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
JICA	Japanese International Cooperation Agency
LQI	Land quality indicators
MBREIS	Mexico Border Regional Environmental Information System
MLRA	Major land resource areas
MVA	Model visualization and analysis
NAL	National agricultural library
NCU	National coordination unit
NGO	Nongovernmental organization
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Institute
OECD	Organisation for Economic Co-operation and Development
PFE	Permanent forest estate
PSGE	Productive sector growth and environment
PSR	Pressure-state-response
PUMS	Public use microdata samples
SARD	Sustainable agricultural and rural development
SIS	Soil information system
SLA	Statistical local area
SLM	Sustainable land management
SOE	State of environment
SOTER	Soil and Terrain Database
SSSA	Soil Science Society of America
STC	Scientific and technical committee
TFP	Total factor productivity
TJ	Terajoules
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VHSI	Vertical habitat structure index
WCU	World Conservation Union
WRI	World Resources Institute

Introduction

Sustainable land management is a knowledge-based procedure that helps guide decisions on land management toward those options that are most feasible and cost effective in achieving land-use intensification, particularly agricultural production, and improved environmental management. As discussed in the new World Bank Rural Sector strategy (World Bank, 1997), the need for agricultural intensificationas well as other demands for increased goods and services from the landis already evident. No less urgent is the requirement for better and more environmentally positive management of rural landscapes.

In the past growth has often been achieved by degrading the natural resource base, but this is no longer acceptable. Increasingly it is being realized that land is a major factor in global life-support systems and that it has intrinsic value beyond agricultural production. Land provides global environmental benefits, such as its role in global geochemical (nutrient) cycles, source and sink functions for greenhouse gases, and filtering of water and pollutants. The challenge, then, is to achieve the dual objectives of intensification and preserving and enhancing the quality of land resources. There is increasing evidence that this is not a utopian dream, but indicators of land quality and sustainable land management are needed to guide us along the way.

Indicators are descriptors that represent a condition and convey information on changes or trends in that condition. They may be used in monitoring and evaluation programs to estimate the rate of change and the impacts. Indicators are already in regular use for economic and social data. For example, gross national product is an indicator of total wealth; life expectancy, infant mortality, and literacy rates are indicators of social well- being. In contrast, few such indicators are available to assess, monitor, and evaluate changes in the quality of land resources or the impact of human interventions in the landscape. This annotated bibliography is one of a series of activities being undertaken by the World Bank, in cooperation with Agriculture and Agri-food Canada and other national and international partners, to correct this void.

Governments and other decisionmakers use indicators to make more informed decisions. At the same time an increasingly better informed publicincluding nongovernmental organizations (NGOs) and other interest groupsuse indicators to monitor decisions being made about land use; that is, indicators provide guidance on actions to be taken, but they are also an important component of national and global cheeks and balances to ensure that decisionmaking is in accordance with the requirements of society. For these reasons ad hoc selection of indicators is no longer acceptable, and indicator programs must be carefully structured, practical, and scientifically sound. However, decisionmakers

at different levels (farm, regional, national, international) require different kinds of indicators depending on the kinds and level of their decisions. The probability of greater relevance, utility, and application of indicators increases if decisionmakers and other stakeholders are involved in the choice of indicators and the development of monitoring systems.

However, useful indicators do not just happen. They require directed and coordinated research programs and strong motivation by decisionmakers to create, maintain, and apply the indicators. Motivation may come from the need for (a) understanding complex systems, (b) a guide to more effective planning and development programs, (c) assessing the long-term social and environmental impacts of projects, (d) justifying funding, or other needs.

Summary

Alarge number and variety of indicator programs are currently being developed or are in place. In most cases these programs are aimed at evaluating sustainability, environmental impact(s), or land management in agriculture, forestry, and conservation. Literature on indicators is rapidly increasing, and it is often difficult and time-consuming to identify reliable information. This bibliography was compiled to assist in this process by compiling available data and information on indicators, organizing and summarizing them, and making them easily accessible through the WWW, e-mail, and as printed reports. The review is useful for research on indicators of sustainability, as well as for decisionmakers faced with implementing a sustainable land management component in rural development projects. It is a stepping-stone toward development of improved programs to monitor and report progress toward environmental sustainability.

This bibliography is a review of available information on indicators of sustainable land management and land quality. As expected, the emphasis is on agricultural land management, but references to forest land management and, to a lesser extent, to conservation, are included where available. Only those references describing specific indicators or those describing the results of indicator programs (agrienvironmental, forestry programs) are included.

The report reviews data and information available in the scientific literature and on the World Wide Web (WWW). Unpublished literature is included when judged to be reliable and peer-reviewed. The reviews are annotated to provide the reader with expanded interpretations of the information found in the publications. In addition a review of available URL sites was conducted, and the most useful sites relating to sustainable land management and land quality are annotated. These sites are intended as points of departure (bookmarks) for anyone wanting further information from the internet.

The review found that while a wealth of information exists on soil properties, along with detailed procedures on how to measure soil properties in the field, this information is generally too detailed and data-demanding to be suitable as indicators of land quality. Similarly, the review revealed more references to indicators for sustainable land management than for land quality. This is as expected, since the concept of and research on sustainable land management predates research on land quality by several years. However the two approaches are highly complementary, since land quality indicators form the biophysical descriptors for sustainable land manage-

ment. A comparison of the concepts of soil quality, land quality, and sustainable land management can be found in appendix 1.

Developing Indicators

Much of the current effort on indicator development was carried out in conjunction with national State of the Environment reporting, but some international organizations, such as the OECD, World Bank, and UNEP are attempting to coordinate the development of indicators. Most of the work so far has been theoretical, with organizations identifying potential indicators, suggesting possible units of measurement, and developing research strategies for national, regional, and local application. This bibliography documents many of these initiatives.

Although much of the work is still conceptual, the first empirical studies are beginning to appear, and these will help identify the kinds of indicators to be developed, the methods (algorithms) to be used, and the thresholds values (level beyond which a system undergoes significant change) for indicators of sustainability. Which indicators are selected and how they are measured can significantly alter the outcome. In a State of the Environment exercise in Australia, Chisholm and Dumsday (1995) compared a scale developed in Australia with a rating based on criteria developed by the Green League of Nations. They found that the country scored higher using the national scale than when the Green League of Nations criteria were used. This underscores not only the need for caution when adopting criteria from other regions but also the possibility of bias with local systems.

Common (Generic) Indicators

Generic indicators, or at least common indicator themes, are essential as national and international standards for purposes of comparison, for monitoring and evaluating sustainable land management, and in order to focus research on those indicators that are strategically the most important. Results from a workshop in Canada on sustainable land management and the development of a research program on land quality indicators (appendix 1) indicate that a high degree of consensus on such indicators can be achieved.

The workshop in Canada (Dumanski 1994) convened highly experienced researchers from many parts of the world to debate and recommend common indicators for sustainable land management for the major ecoregions of the world. Table 1 illustrates the results of these recommendations, grouped under the five pillars of the international Framework for Evaluation of Sustainable Land Management (FESLM). The workshop also concluded that indicators must be tailored to reflect the land uses, management practices, and environment where they will be applied. No single indicator could

Table 1. Common (generic) indicators for monitoring and evaluating sustainable land management

Productivity	*Security*	*Protection*	*Viability*	*Acceptability*
Crop yield	Soil cover	Soil quality/quantity	Net farm profitability	Use of conservation practices
	Yield variability	Water quality/quantity	Input use efficiency	Farm decisionmaking criteria
	Climate	Biological diversity	Pesticides	
			Fertilizers	
			Nutrients	
			Off-farm income	
			Return to labor	

Table 2. Core (generic) land quality indicators for which international agreement has been achieved

Indicators to be developed in the near term	*Indicators requiring longer term research*	*Indicators being developed by other networks*
Nutrient balance	Soil quality	Water quality
Yield gap	Land degradation	Forest land quality
Land use intensity	Agrobiodiversity	Rangeland quality
Land use diversity		Soil pollution
Land cover		

determine sustainable land management with our current state of knowledge, and the best approach is to develop sets of related indicators on common issues or themes. A cursory comparison of the recommended indicators (table 1) with indicators being developed in other regions shows a high degree of complementarity.

A similar exercise under the global Land Quality Indicators (LQI) program achieved international agreement on a set of "Core LQIs" as international reference standards (table 2) (see Pieri and others 1995).

These generic, or core, indicators focus research and development activities on those indicators that have been judged to be the most useful. However many other studies have identified other indicators, and these also are referenced in the bibliography.

Site-Specific Indicators

Many indicators have common themes across several domains, but to sort out what might be transferable from site-specific data of other domains and prioritize the needs of the current situation, evaluations must also be targeted to the constraints within the area under examination. Appendix 2 provides some guidance on how to apply indicators in rural development projects.

Research on site-specific indicators, especially in the developing world, is very sparse. While some work underway in the developed world can be utilized on a site-specific basis, in many cases the data required for the indicator are not available (such as databases of soil, climate, land use, and management inputs).

Several of the centers within the Consultative Group on International Agricultural Research (CGIAR) are conducting research on indicators of sustainable development. For example, the International Center for Forestry Research (CIFOR) in Indonesia has launched a program to determine criteria and indicators in the forestry sector; the International Board for Soil Research and Management (IBSRAM) is researching indicators at the farm level, including local farmer knowledge; and the International Center for Living Aquatic Resources Management (ICLARM) is researching sustainability indicators for integrated aquaculture-agriculture farming systems. Becker (1997) provides a comprehensive summary of research procedures currently used in the CGIAR Centers and by others to evaluate agricultural sustainability.

How to Use the Bibliography

The bibliography is a reference base for information on agro-environmental indicators, as well as a useful reference guide to methods being used for indicator research. The references are organized alphabetically and by category. The bibliography is available in hard copy and through the WWW

(http://www.ciesin.org/LW-kmn). The electronic version can be searched by author, by key word, by the pillar (of the FESLM), by specific indicator, and by scope (categories listed under NOTES). Thus searches can be for specific keywords or combinations (for example, degradation, South America); by any of the pillars of the FESLM (production, security, protection, viability, acceptability); by region or country; or by scope (national, local). This flexibility enables the user to scan the available information and identify whether publications are pertinent, how they can be obtained, and where more detailed information is available.

Annotated Bibliography

Acton, D.F., ed. 1994. *A Program to Assess and Monitor Soil Quality in Canada: Soil Evaluation Program Summary*. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 210 pp.

NOTES:
Report identifies the requirements and provides a framework for soil quality evaluation. It summarizes the development of improved capabilities for assessing soil quality and for analyzing the impact of soil degradation on soil quality and crop productivity. It also provides insights into the status of soil quality in Canada that have been forthcoming as part of the system developments.

KEY WORDS: Soil quality

Acton, D.F .and Gregorich, L.J., eds. 1995. *The Health of Our Soils: Toward Sustainable Agriculture in Canada.* 1906/E. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 138 pp.

NOTES:
The health of Canada's agricultural soils is portrayed by presenting key findings of recent research on:

Soil organic matter and soil structure

Processes that degrade soil, including erosion, salinization, and chemical contamination

Groundwater contamination

The role of land use and management practices in degrading, maintaining, or improving soil quality.

KEY WORDS: Soil quality

Adams, W.M. and Mortimore, M.J. 1997. "Agricultural Intensification and Flexibility in the Nigerian Sahel." *The Geography Journal* 63:150-60.

ABSTRACT: This paper discusses evidence of agricultural intensification in the Sahelian zone of northeast Nigeria, drawing from a five-year monitoring study of soils, cultivars, and livelihoods

across environmental and demographic gradients. The paper stresses the importance of flexibility in ecological management and in economic activities as components of rural livelihood strategies. In the villages studied the intensity of agricultural operations decreases with annual rainfall amount. However the flexibility in options within both cropping systems and off-farm employment is greatest in the drier villages. The nature of this flexibility and its relevance to debates about intensification are discussed.

KEY WORDS: Nigeria, agricultural intensification, Sahel, drought, rural development

NOTES:
Pillars: Production, viability, acceptability
Indicators: Labor ha-1, landesque capital, cultivation frequency, percent of land cultivated, farming technologies, soil fertility management, crop-livestock integration
Scope: Local, regional
Unit of measurement: Varied

Agricultural Economics Research Institute. Unpublished. "Development of an Agricultural Nutrient Balance Indicator: Progress Report from Finland." COM/AGR/CA/ ENV/EPOC/RD(96)88. Organisation for Economic Co-operation and Development, Paris. 8 pp.

NOTES:
Pillars: Viability, protection
Indicator: Agricultural nutrient balance
Description: Nutrient balance is an indicator of how many nutrients are lost to the environment in the production process.
Purpose: Nutrient balances have been calculated in Finland for the past five years. Most of the calculations are done at the farm level. Specifically, these farm-level calculations are conducted on organic farms where nutrient management is an essential practice, and information on the nutrient flows is the cornerstone for the production planning.
Scope: Farm, but can be expanded to regional and national
Production method: Organic
Unit of measurement: Ratio
Farm Gate Balance: The amount of purchased nutrient inputs compared to the nutrient contents of outputs sold from the farm.
Surface Balance: Nutrients entering versus exiting from the soil.
Methods of measurement:
Farm Gate Balance: Nitrogen and phosphorous contents of inputs are compared to corresponding figures in the outputs. Further, some other components that are not purchased are included in the calculation sheet, such as the deposition of nitrogen from the atmosphere and biological fixation of nitrogen from the air.

+ Nutrient contents purchased inputs (fertilizers, manure, fodder and animals)
+ Deposition of nitrogen
+ Biological nitrogen fixation
- Nutrient contents of the sold products (milk, meat, manure, grains)
= Farm gate balance.

Surface Balance: With regard to inputs the calculation takes into account the use of chemical fertilizers and manure. Deposition of the nitrogen and biological nitrogen fixation can also be taken into account. For outputs, the nutrient contents of harvested crops are calculated for gross surface

balance. If we take into account the evaporation of the nitrogen in the manure and the fact that all nitrogen in manure is not in a feasible form for plants to be utilized, we get a net surface balance.

+ Nutrient content of the purchased fertilizers
+ Nutrient content of manure used on farm
+ Deposition of nitrogen
+ Niological nitrogen fixation
- Nutrient content of the harvested crops
- evaporation and non-feasible nitrogen
= Surface balance (gross) = Surface balance (net)

Assessment of Available Data: Calculating nutrient balances at the farm level is straightforward but tedious. Keeping account of all nutrients entering the system is a difficult task in animal husbandry (keeping track of nutrients in foodstuffs). Thus this approach may require too much extra work to be feasible in practice.

The approach of surface balance suits fairly well for present data collection processes. Regional or country level calculations of surface balance are also simpler to carry out. The data is generally available for different regions, for example, animal numbers and crop production. But there are two methods to estimate fertilizer usage for nutrient balance calculation.

Coefficients can be used to calculate the uptake of nutrients by crop. However this does not tell anything about the real fertilizing quantities. For example, in the case of poor weather conditions the yields lag behind normal yield levels. Thus in using crop uptake functions there may not seem to be much nutrient surplus, but as the farmer may still have been fertilizing on average risk level, the actual nutrient run-offs may have been quite high. Therefore, using crop uptake functions we do not always capture the real nutrient surpluses.

The second approach is to relate the data more closely to actual use. If there are fertilizer companies on the market or selling and buying of fertilizers takes place over national borders, the situation becomes more complicated. Alternatively, a census could be used for assessing the real fertilizing levels for different crops on different regions.

Limitations: Nutrient balances do not precisely tell where the nutrient losses emerge from or to what extent the losses leach to the watercourses or discharge to the air.

One major question concerning the feasibility of nutrient balances as an indicator is the problem of external factors, such as weather and soil type, affecting the build-up of the surplus. Because of the weather yield levels vary from year to year.

KEY WORDS: Viability, protection, nutrient balance

Armstrong, T. and Clark, Robert G. 1996. "Correlates of Biological Diversity on Saskatchewan Farmland," pp. 1317 in Stushnoff, C.T., ed. *Proceedings of the Second Sustainable Land Management Workshop,* University of Saskatchewan, 20 February 1996. Agriculture and Agri-Food Canada, Saskatoon, SK. 29 pp.

NOTES:
Introduction: Agriculture has produced widespread loss and degradation of natural habitats in many areas of the Canadian prairies, but in recent years agricultural policies have been designed and promoted to conserve soil and water quality and to indirectly benefit the environment, including wildlife. These new policies recognize that environmental sustainability is a central pillar of sustainable agriculture. However several questions remain unanswered regarding direct and indirect benefits of soil and water conservation practices to wildlife. Does retaining stubble

via low-till systems, including zero-till, provide productive habitat for wildlife? What are the implications of increased use of pesticides and fertilizers for wildlife and its habitat, including wetlands? The degree to which natural habitats are exposed to agrochemicals and whether such exposure is detrimental is not yet certain. Comparisons of habitat quality, wetland, and wildlife populations across farming systems, especially conventional versus conservation tillage farms and side-by-side comparisons of conventional and organic farms, will help to answer these questions and guide policy, as well as provide assistance to farm producers.

KEY WORDS: Protection, biodiversity

Banerjee, R. 1996. "Summary of Activities in Fiscal-Year 1995-96." Report 14. Environment Bureau, Policy Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 23 pp.

NOTES:
Summarizes activities of Agri-Environmental Indicator Project for 1995-96 fiscal year and provides a description of indicators under investigation

Pillar: Protection
Indicator: Risk of water contamination
Description: Identifies trends in the risk of water contamination from agrichemicals. The indicator will track primary agriculture's success in minimizing water pollution risks and identify areas at higher relative risk. The components of this indicator are nutrient contamination risk and pesticide contamination risk.
Unit of measurement: Ratio of the potential contamination concentration (mg/L) to the maximum allowable concentration (mg/L). Indicator may be reported in risk classes.
Data: Precipitation, evapotranspiration, nutrient inputs, nutrient outputs, crop yields, livestock densities, pesticide use, soil characteristics, land management practices, water quality (see MacDonald and Gleig 1996)

Pillar: Protection
Indicator: Agroecosystem biodiversity change
Description: The species abundance/diversity component measures changes in diversity and abundance of soil fauna and possibly other species groups in relation to major agricultural cropping systems. The habitat availability component will report on changes in the availability of broad habitat types such as wetlands and woodlands.

Unit of measurement:

The unit of expression for species abundance/diversity has not been determined.

The habitat availability component of this indicator will be expressed in change in area and ratio of unimproved pasture and other habitat types to total farmland.

Data:

Species abundance/diversity: Species abundance and taxonomic richness of groups of non-domesticated biota inhabiting agroecosystems and major representative cropping systems

Habitat availability: Area of unimproved land for pasture, grazing, or hay and eventually the area of grasslands, wetlands, and woodlands

Pillar: Protection
Indicator: Soil degradation risk
Description: Reports trends in the extent, severity, and vulnerability of agricultural lands to soil erosion, salinization, and change in soil organic matter levels. The indicator will identify areas of

higher relative risk of degradation and measure progress in managing agricultural lands sustainably.

Unit of measurement:

The soil erosion (water, wind) component of this indicator will be measured in tonnes/ ha/yr, expressed in 5 classes of risk (tolerable, low, moderate, high, severe).

Soil salinization will be expressed in dimensionless multiplicative index (1 to 40) divided into 3 classes of salinity risk (low, moderate, high).

Units of expression for the soil organic matter component have not been determined.

Data:

Erosion: Estimated erosion, percentage change in erosion rate; Universal Soil Loss Equation "C" factor, erosion reduction by crop residue

Salinization: Electrical conductivity, land area, topography, net aridity (climate), and ratio of permanent cover to summerfallow (see Eilers and others, 1996)

Soil Organic Matter: To be determined

Pillar: Viability
Indicator: Input use efficiency
Description: Consists of two components: irrigation by application system efficiency and use efficiency for fertilizer/pesticide/energy. The irrigation application system efficiency component tracks the efficiencies of various application systems and the land area upon which water is applied by each of these systems. The fertilizer/pesticide/energy-use efficiency component reports input use efficiency (productivity) by measuring long-term trends in the amounts of each input used per unit of aggregate production output.

Unit of measurement:

Irrigation by application system efficiency is expressed as the percentage of the water that passes through the applicator that is used by the crop.

Fertilizer/pesticide/energy-use efficiency is expressed as a ratio of inputs over outputs expressed as an index with the base year set at 100.

Data:

Irrigation: Information available from research and field trials on the efficiency of the application systems tracks the land area being irrigated and the application system in use.

Fertilizer/pesticide/energy: Aggregate fertilizer, pesticide, and energy inputs (implicit quantity in constant dollars) and aggregate primary output of crops (grains, oilseeds, forages, fruits, vegetables, and so forth) and livestock (cattle, hogs, dairy poultry); total use; intensity of use; and use efficiency (see Narayanan, 1995)

Pillar: Acceptability
Indicator: Farm resource management
Description: The soil cover and management component estimates the proportion of cultivated land falling under various classes of soil residue cover (low, medium, high) and the adoption rate of selected soil conservation practices. Farm inputs management tracks the extent of adoption by farmers of selected best management practices for inputs (fertilizer, manure, and pesticides).

Unit of measurement:

Soil cover and management is expressed as a percent adoption of soil conservation practices and trends in areas of cultivated land with high, medium, and low soil residue cover.

Farm inputs management will be expressed as the distribution and frequency of use of the identified inputs management practices.

Data:

Soil cover/management: The proportion of farmland under various crops, summerfallow, pasture, conventional tillage, conservation tillage, no-till; the adoption of selected erosion control practices

Farm inputs management: How liquid manure is stored; how commercial (chemical) fertilizer is applied; whether any pest control methods other than chemical pesticides are used (see Hillary and others, 1995)

Pillar: Protection
Indicator: Agroecosystem greenhouse gas (GHG) balance
Description: Tracks the accumulation and release of the principal greenhouse gases from the agricultural sector and reports the net integrated balance

Unit of measurement: Net emissions and/or uptake of each greenhouse gas will be expressed in tonnes per year. The integrated GHG balance will be expressed in tonnes of CO_2 equivalent units.
Data: Fertilizer use, cropping patterns, fossil fuel consumption, animal populations, manure production and storage, estimated soil carbon flux, and other related factors (see Smith and others, 1995)

KEY WORDS: Protection, viability, acceptability, soil quality, water quality, biodiversity, inputs, emissions, resource management

Batie, S.S. 1995. "Developing Indicators for Environmental Sustainability: The Nuts and Bolts." Special Report 89. World Bank, Washington, D.C. 164 pp.

NOTES:

Conference proceedings provide a summary of research being done in the area of indicators including updates from Australia, Canada, the US, and the OECD, as well as general papers on the challenge of defining sustainability and economic principles of indicator development.

KEY WORDS: Indicators (general)

Batjes, N.H. 1996a. "Global Assessment of Land Vulnerability to Water Erosion on a 1/2° by 1/2° Grid." Report 96/08, International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands. 16 pp.

ABSTRACT: A simple methodology for assessing the risk of water erosion at the global level is presented. It uses a 1/2° latitude by 1/2° longitude soil database developed at ISRIC and auxiliary databases on climate and land cover with a similar spatial resolution. Area estimates are presented for (a) susceptible areas, as determined by rainfall erosivity, topography, and soil erodibility, and (b) vulnerable areas, as further determined by the pressure of current land use. Model output for vulnerability is evaluated against observed data on severity of soil degradation by water, as presented on the map of human-induced soil degradation (GLASOD). Cross-tabulation of the vulnerability and GLASOD subsets gave a significant Cramer's correlation coefficient of 0.72 ($P < <0.005$). Thus a fair geographic agreement was observed between the grid cells considered vulnerable to water erosion, under current conditions of land cover, and regions in which water erosion occurs currently.

The qualitative model can serve to raise awareness on issues of soil degradation by water at the global level by identifying regions at risk, where more detailed studies are needed. However it does not provide any information on the actual rate of erosion at field scale or on the associated decrease in crop productivity and biodiversity. The study of productivity changes associated with water-erosion at different scales is currently an important topic on ISRIC's research agenda.

KEY WORDS: Land degradation, vulnerability, water-induced soil erosion, global model, GIS, GLASOD

Batjes, N.H.. 1996b. "A Qualitative Assessment of Water Erosion Risk Using 1:5 M SOTER Data: An Application for Northern Argentina, South-east of Brazil, and Uruguay." Report 96/04. International Soil Reference and Information Centre, Wageningen, The Netherlands. 14 pp.

ABSTRACT: A simple Pressure-State-Response model for assessment of the risk of water erosion at the continental scale is presented, in which soil erodibility, slope, rainfall erosivity, and land use (a coarse indicator of human-induced pressure on the land) are the main controlling factors. The qualitative model uses input data from the 1:5 million scale Soil and Terrain Database (SOTER) and a revised version of the FAO's Agro-Ecological Zones map. The methodology was developed and tested for a pilot area bounded by latitude 49° W to 61° W and 28° S to 35° S, covering parts of Argentina, Brazil, and Uruguay (about 656×103 km2). This initial desk study shows the potential of the 1:5 million scale SOTER database for identifying areas at risk from water erosion. However there was little possibility to evaluate the outcome of the model against 'ground-truth' or to quantify effects of food production on water erosion, and vice-versa, for which more detailed follow-up studies are needed.

NOTES:
Pillar: Protection
Indicator: Erosion
Scope: Regional, national
Unit of measurement: Qualitative, comparative

KEY WORDS: Degradation, soil erosion, GIS, SOTER, LATIN AMERICA.

Becker, B. 1997. "Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches." "Issues in Agriculture" 10. CGIAR Secretariat, Washington, D.C. 63 pp.

SUMMARY: The report is one of the most comprehensive literature reviews of the concepts and procedures for assessing sustainability. It discusses sustainability from philosophical, environmental, economic, social, and cultural perspectives and provides recommendations on indicator development and operationalization of the concepts. The report includes an overview of current sustainability indicators, as follows:

Economic Indicators:

- Modified gross national product
- Discount rates
  - Depletion costs
  - Pollution costs
- Total factor productivity
- Willingness to pay
- Contingent value method
- Hedonic price method
- Travel cost approach

Social Indicators:

- Equity coefficients
- Disposable family income
- Social costs
- Participation
- Tenure rights

Environmental Indicators:

- Yield trends

Coefficients for limited resources

Depletion rates

Pollution rates

Material and energy flows and balances

Soil health

Modeling

Empirical

Deterministic-analytical

Deterministic-numerical

Bioindicators

Composite Indicators:

Unranked lists of indicators

Scoring systems

Integrated system properties.

NOTES:
Pillars: Productivity, security; protection, viability, acceptability
Indicator: Varied, as listed above
Scope: Local to national
Unit of measurement: Varied

KEY WORDS: Sustainability, indicators, economic, environmental, social

Benites, J.R. and Tschirley, J.B. 1997. "Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development." *FAO Land and Water Bulletin* 5. Proceedings of a Workshop on Land Quality Indicators for Sustainable Resource Management organized by the Land and Water Development Division, FAO Agriculture Department, and the Research, Extension, and Training Division, FAO Sustainable Development Department, 2526 January, 1996. FAO, Rome, Italy. 212 pp.

Summary Report and Conclusions: A workshop entitled "Land Quality Indicators for Sustainable Resource Management," held at FAO Headquarters in Rome, was attended by FAO technical staff and invited participants from Agriculture and Agri-Food Canada, the International Soil Reference and Information Center, UNEP, World Bank, and private consultants. A total of 14 papers were given over three sessions. The workshop provided a technical forum to discuss issues relating to land quality indicators (LQIs) and their use by planners and policymakers. LQIs can be used at the national and district levels to assess the qualities of land, monitor its changing conditions, and formulate policies and development programmes that take land quality into account.

There is much concern that land quality is changing, but that there is not enough formal monitoring of what is changingin what direction or at what rate. Perceived improvements in land quality attributable to development programmes and projects are provided more by guesswork and wishful thinking than by the use of indicators or the results of planned monitoring.

Discussions in FAO and numerous international fora have contributed to the ongoing debate on indicators of sustainable development. Due in part to the range of interest and disciplines involved, there is not yet a consensus on the specific features of sustainability indicators or their strengths and weaknesses. How indicators are used can help to identify important problems and successes or may lead to confusion or misinterpretation.

The FAO already plays an important role in collating information related to LQIs, but an important emerging challenge is to improve the quality of existing data: identify what additional

data are needed; geographically reference FAO data; develop linkages among the natural resources, social, and economic dimensions; and especially to make data more easily accessible to the developing countries.

Specific Workshop Objectives:

- Seek consensus on major issues related to measuring land quality
- Move toward an integrated set of LQIs for assessing the resource base and monitoring change conditions

- Identify sources of data and information required to develop indicators
- Establish linkages between social/economic issues and LQIs (and promote the use of LQIs by economists and social scientists)
- Identify opportunities for practical testing plus application of LQIs in the countries.

Workshop Results

Major issues related to measuring land quality: The workshop concluded that different indicators are needed to track changes in each of the land's main components (and their subdivisions) and that the data and information needs are so diverse, ranging from farmers to politicians, that a single, core set of indicators is probably not possible to develop over the short term.

Some generic indicators were presented in the framework of an integrated, holistic approach to land-use decisions and management and the changes in important biophysical and socioeconomic attributes of land units that must be monitored, especially for:

- Changes in the condition of land resources, both positive and negative
- Changes in areas arising from different land uses
- Rates of adaptation and adoption of recommended/suggested practices
- Changes in farm management practices
- Changes in yields and other outputs resulting from project interventions or other development
- Rural development issues such as land tenure, population density
- Water resources
- Fisheries and aquaculture
- Forest management
- Land-soil nutrients.

Different levels of planning and programming need to be distinguished. For farm-level change detailed information is best achieved from observations and records from single farms. One also needs to find out over what area and on what percentage of farms similar results may be found. The lower the level the more detailed the indicators become.

The amount of detail that needs to be recorded increases as one moves along the sequence of questions: (a) Is any change occurring, and in what directionpositive or negative? (b) What is changing? (c) How great is the change? (d) How rapidly is it occurring? (e) What processes of change are in motion? (f) Why have these processes of change been set in motion?

The Pressure-state-response (PSR) framework was generally accepted, but questions were raised about its limitations in terms of cause and effect relationships; responding to changing state conditions; and ability to address biophysical, social, and economic issues in a holistic manner. The importance of PSR being issue- or objective-driven and not indicator-driven, was underlined.

The time aspect was also raised, especially change and trend analysis as being more useful than static, assessment-types of information. For time-to-time comparisons the same individuals/groups/farms/sites should be used to provide directly comparable time-series of data.

Regarding integration of different indicators within FAO aimed at measuring sustainability, the agro-ecological zoning (AEZ) approach was endorsed with the recommendation that it be expanded to a more detailed scale and include social and economic information layers.

Some open issues and problems to be solved include:

- Sources of data are numerous. but how can they be best structured and classified?

How to integrate and link natural science with social science indicators and approaches?

Whether "simple" indicators are operationally possible or desirable?

Pilot case studies should be considered to answer the above questions.

Management and interpretation of data and information to develop indicators: It is important that available data and information are interpreted adequately and that the resulting indicators are communicated effectively and quickly in a manner which can be easily understood. The task of monitoring staff therefore includes:

Reducing the mass of detail into clearly labeled tables

Integrating similar materials from various parts of the information system

Assembling results over time or by geographical area, so that trends and inter-area comparisons become apparent

Ensuring that analyzed and interpreted material is credible and, if unexpected or unusual, backed by specific supporting evidence (quality assurance)

Preparing brief, concise, and clear narrative material that is timely and designed for the specific target audience.

Valuable data are useless if they are not analyzed and presented in a decision-support context. But an excess of analysis using statistical techniques misapplied to data that do not fulfill statistical requirements may result in presentation of results with spurious reliability and coefficients that the user does not understand.

Testing and application of LQIs in countries: Field projects are one way to gain experience and test methods that can improve the measurement of changes in land qualities, but many countries are also capable of carrying out their own LQI programmes, and this is indeed highly desirable. Country studies could address:

Examples of improvements in land quality (for example, results of soil conservation and land-use planning case studies)

Country case studies based on a matrix of AEZ x land-use intensity x data availability

Use of land quality information for policy analysis

Development of a meta-database of land quality information sources

Development of improved AEZ case studies

Experience in compiling farm-level indicators

Experiences with regard to data quality and aggregation

District level land-use mapping by farmers

LQI data aggregation.

Guidelines are needed to assist analysts in following common approaches to studying and developing land quality indicators.

NOTES:
Pillars: All
Indicators: Varied, many are mentioned without explanation of derivation
Scope: Local, regional, and global
Unit of measurement: Varied

KEY WORDS: Indicators, sustainable agriculture, rural development

Berger, A.R. 1996. *Tools for Assessing Rapid Environmental Changes: The 1995 Geoindicator Checklist.* ITC Pub. 46 ITC, Enschede, The Netherlands.

ABSTRACT: The evolutionary history of the earth and the biosphere has been punctuated throughout by environmental changes that reduced or enhanced the capacity of terrestrial landscapes to

provide a place for healthy life. The condition of the environment at any time reflects not only human influences but also natural processes and phenomena that may be causing change, whether or not people are present. Moreover, away from obvious sources of human disturbances (cities, waste disposal sites, mines, deforested areas) it may be extraordinarily difficult to separate the effects of human actions from those caused by "background" natural processes. A newly compiled checklist of geological indicators of rapid environmental change illustrates this point. Listed in the report are 27 earth system processes and phenomena that are liable to changein less than a centuryin magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators have been developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for State of the Environment reporting. As descriptors of common earth processes that operate in one terrestrial setting or another, geoindicators represent collectively a new kind of landscape metric, one that concentrates on the nonliving components of the lithosphere, pedosphere, and hydrosphere and their interactions with the atmosphere and biosphere (including humans). The geoindicator checklist was developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning.

NOTES:
Pillars: Protection
Indicators: Coral chemistry and growth patterns; desert surface crusts and fissures; dune formation and reactivation; dust storm magnitude, duration, and frequency; frozen ground activity; glacier fluctuations; groundwater quality; groundwater chemistry in the unsaturated zone; groundwater level; karst activity; lake levels and salinity; relative sea level; sediment sequence and composition; seismicity; shoreline position; slope failure (landslides); soil and sediment erosion; soil quality; streamflow; stream channel morphology; stream sediment storage and load; subsurface temperature regime; surface displacement; surface water quality; volcanic unrest; wetlands extent, structure and hydrology; wind erosion
Scope: General
Unit of measurement: Varied

KEY WORDS: Geological, indicators, geosphere, lithosphere, pedosphere, hydrosphere, land use, degradation.

BMZ and GTZ. 1995. "Promoting Sustainable Soil Management," in *Development Cooperation: A Guide.* Federal Ministry for Economic Cooperation and Development (BMZ) and Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn. 57 pp.

NOTES:

The report highlights the role of sustainable soil management for an environmentally viable development overall. It is intended as a guide for promoting sustainable soil management as part of German development policy.

The guide is made up of two major parts: the first, "Policy for Promoting Sustainable Soil Management in Developing Countries," locates sustainable soil management in development policy, looking in particular at the correlation between sustainable soil management and sustainable development.

The second part deals in more detail with the topic and lays the conceptual foundation for planning projects in soil management. It presents a general picture of the form and scale of soil degradation and describes the major degradation processes and their causes. The last part deals with designing measures to promote sustainable soil management. Specific measures are needed for specific conditions; therefore the guide does not specify approaches or measures for indi-

vidual agroecological zones and economic areas, but rather confines its attention to general principles.

KEY WORDS: Sustainable land management, soil quality

Bomans, E. Vanogeval, L. Vandendriessche, H. and Geypens, M. Unpublished. "Development of an Agricultural Soil Quality Indicator: Progress Report from Belgium." COM/AGR/CA/ENV/EPOC(96)85. Organisation for Economic Co-operation and Development, Paris. 19 pp.

NOTES:
Pillar: Protection
Indicator: Soil quality
Description: The area of agricultural land affected by a decreased inherent capacity to produce agricultural crops of an appropriate quality and in adequate quantities, in a sustainable manner, within the given context of climate and available technology
Scope: National, regional, local
Unit of measurement: Ha. or percentage of total agricultural land
Methods of measurement: This indicator on soil quality will mainly concentrate on irreversible, or only slowly reversible, phenomena of degradation and deterioration, such as soil erosion, depletion of organic matter, or pollution by heavy metals. There is less focus on factors that can be rapidly corrected such as soil fertility, in the sense of the capacity of the soil to provide plant nutrients. However, in the case of continuously negative nutrient balances, it might be useful to consider including this factor (and perhaps others) into the indicator.

For the time being, the following attributes will be considered to be included in the indicator. Other attributes may be added at later stages according to prevailing conditions, such as:

Wind Erosion: Little data available.

Water Erosion: Specific criteria for acceptable levels of soil erosion have not yet been established. In the meantime the internationally accepted limit of 10 tonnes/ha/year or 1 mm per year is being used (this is the average rate of soil formation).

Salinization: No data on salinization of soils.

Contamination: Term covers a wide range of components that can be split according to type (organic, inorganic) and to origin (atmosphere, fertilizers, manure, sludge, pesticides).

Soil Structure: Compaction risk could be derived from soil maps (susceptibility to compaction) and combined with data on soil management (type of machinery, average plot size, crops, and so forth).

Waterlogging: Drainage class is the second criterion of Belgian soil classification and areas suffering from waterlogging can easily be located on the soil map.

Acidification (soil pH): Acidification of agricultural land is attributed to several agents, but mainly to deposition of acidifying substances and the use of manure fertilizers. On both parameters substantial data is available. If necessary these data could be combined with data from the soil map to calculate risk of acidification of the agricultural land.

Organic Matter Content: Belgian soil map provides a great detail of information on the organic matter content of top soil. However the map must be seen as a historic document for reference since it has not been updated since 1960s. A number of projects are looking at monitoring organic matter status of soil.

Each attribute is evaluated in its own specific way to receive a quotation from 1 to 4 based on a general appreciation of the effect or of the risknone, slight, moderate, or severe. Soil quality is considered to be as good as its worst attribute.

Limitations: Authors tested their method on the Belgian situation. It became clear that the proposed indicator cannot be completely worked out yet, using existing information.

KEY WORDS: Protection, soil quality

Bryant, D. 1995. "The Ecosystem Indicators Model: A Concept Proposal." World Resources Institute, Washington, D.C. 6 pp.

NOTES:

The World Resources Institute proposes to develop a GIS prototype indicator application useful for guiding national-level conservation decisionmaking and related land-use planning, as well as for meeting reporting requirements spelled out in the Biodiversity Convention and Agenda 21. This prototype would build on ongoing collaborative indicator research with the National Institute for Public Health and Protection in the Netherlands to define an indicator framework for assessing anthropogenic pressures on natural and seminatural areas. The indicator application proposed here is based on a conceptual model developed out of this collaborative research, entitled the Ecosystem Indicators Model (EIM).

KEY WORDS: Protection, biodiversity

Cann, M. Dumanski, J. Gameda, S. and Brklacich, M. 1994. "Development of Indicators of Soil Quality and Sustainable Land Management: Using Knowledge and Information Obtained from Innovative Conservation Farmers," in Acton, D.F., ed. *A Program to Assess and Monitor Soil Quality in Canada: Soil Quality Evaluation Program Summary*. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, ON.

NOTES:
Pillar: Acceptability
Indicator: Adoption of innovative conservation practices
Description: Innovative conservation farmers are those who are early adapters and refiners of conservation technologies
Scope: Local
Unit of measurement: A comparison between innovative conservation farmer observations and results of conventional degradation studies
Methods of measurement: A detailed questionnaire was designed to capture the observations of innovative conservation farmers, as well as to identify the indicators used by the farmers to define the symptoms of soil degradation.

The innovative conservation farmers reported the use of percent organic matter as an indicator of soil quality and suggested various sustainable practices that may maintain or increase organic matter content. Indicators of SLM identified by the innovative conservation farmers were:

- Decrease in the area that is summerfallowed
- Increase in acreage allocated to forage or grazing pasture (livestock integration)
- Increased use of winter crops to distribute the workload throughout the year and provide soil cover
- Decrease in field sizes
- Crop diversification by including crops such as legumes or forages in a rotation
- Decrease in the application of commercial fertilizers

Increase in erosion and moisture-control activities such as shelterbelt establishments, grassing of natural waterways, contour plowing, and standing stubble

Increased use of herbicides for weed control on fallow

Improved drainage and recharge/discharge management

Local processing of produce

Extension programs with on-farm demonstration and the availability of new technologies

Increased research activities into conservation practices and new crop varieties

Return of soil organisms such as earthworms

Development of new markets for crops such as winter rye, winter wheat, and forages.

KEY WORDS: Acceptability, resource management

Chisholm, A.H. and Dumsday, R.G. 1995. "Environmental Indicators and Land Resources Policy: An Australian Perspective," pp. 6998 in Batie, S.S., ed. "Developing Indicators for Environmental Sustainability: The Nuts and Bolts." Special Report 89. World Bank, Washington, D.C.

NOTES:

Summarizes Australia's State of the Environment undertaking. As part of the OECD environmental program, member countries have been encouraged to develop their own sets of environmental indicators in collaboration with each other. An unstated objective of the program is to demonstrate to nonmember countries, particularly those of the developing world, that OECD countries are managing their environments responsibly.

Recommended indicators were determined in part by whether or not the relevant data are widely available, or obtainable by measurement or from records, at reasonable cost. It is significant that the list does not include several indicators that are often favored, at least in principle, by scientists. State of Victoria, probably has the best data sets of any state in Australia, but still has important gaps.

Recommended indicators	*Other indicators*
On-site	
Vegetative cover (type and extent)	Soil erosion
Crop yields and protein content	Soil structure
Soil nutrient inputs and outputs	Soil nutrient status (N, P, K, Ca)
Chemical residues in crops	Soil pH
Salinity (salt-affected and salt-prone areas)	Agricultural chemicals and fuel usage
	Chemical residues in livestock
	Soil biological indicators
	Native flora and fauna
	Pest plants and animals
	Waterlogging
	Loss of agricultural land to other uses
Off-site	
Groundwater hydrology and quality animals	Agriculturally related pest plants and
Surface water hydrology and quality	Native flora and fauna
Sediment accumulation in chemical residues	Human health effects of agricultural chemical use
Chemical residues in native biota	
Specific areas	
Chemical residues in soils (onsite)	
Chemical residues in sediments (offsite)	

Source: Commissioner for the Environment (Victoria, Australia).

The OECD and others recognize that Total Factor Productivity (TFP) of an agricultural system, calculated as the change in the ratio of the index of measured outputs to that of measured inputs, provides a useful indicator of sustainability. This measure could redefine a sustainable agricultural system as one with constant or increasing TFP *and* output over time.

Limitations: While land is included in the calculation of TFP, it is not measured in a way that fully captures any decline or improvement in its quality. TFP does not account for farmers' management inputs and fails to include allowance for damage to other ecosystems. Rankings depend on measures applied.

Environmental indicators and their normalizing units

Indicator	*Green League of Nations*	*Bruntona where different*
CO2 emissions	From energy production/capita	From energy production/km2
Nox emissions	Per capita	Per km2
Sox emissions	Per capita	Per km2
Water abstraction	Per capita	As percentage of renewable water resources
Sewage treatment	Per cent of population	
Protected areas	Per cent of total land area	
Threatened species	Per cent of total mammal & bird species	
Waste generation	Per capita	Per km2
Energy intensity	Primary energy supply per $1,000 of GDP	
Transport intensity	Passenger km in private vehicles per capita	Passenger km in all vehicles per per capita
N fertilizer application	Per km2 of arable and permanent cropland	

a. Brunton, R. 1994. Environmental Indicators: Sustainable Development or Political Tool? Tasman Institute Occasional Paper B2. Melbourne.

Used to compare Australia in relation to other OECD countries. Depending on how the indicators are measured, the rates differ, with Brunton's method being higher than those of the Green League.

KEY WORDS: Protection, viability, soil quality, water quality, biodiversity, nutrient balance, inputs

CSD. 1996a. *Indicators of Sustainable Development: Framework and Methodologies.* Commission for Sustainable Development, United Nations Department for Policy Coordination and Sustainable Development, New York, New York. World Wide Web http://www.un.org/dpcsd/index.html.

ABSTRACT: In the four years since the Rio Earth Summit (UNCED) there have been many initiatives to promote sustainable development. Indicators are useful tools to gain insight regarding the progress made in achieving sustainable development. Agenda 21 calls for countries, international organizations, and nongovernmental organizations to develop and use indicators of sustainable development.

Building on many national and international initiatives aimed at developing and using indicators, the Commission on Sustainable Development in 1995 adopted a work program on indicators for sustainable development. The program includes an initial set of 130 indicators.

To facilitate the use of these indicators and test their practicability at the same time, methodology sheets have been developed for each of them. This publication presents these methodology sheets.

The goal is to have a good set of indicators for sustainable development by the year 2000.

NOTES:
Below is a brief description of indicators that are applicable to SLM.

Qualitative Assessment of the Condition and Level of Sustainable Use of Natural Resources in Mountain Areas
Four subindices; three are relevant to FESLM

Pillar: Protection
Indicator: Extent of protection of soil

Pillar: Protection
Indicator: Extent of degradation

Pillar: Productivity
Indicator: Measure of productivity
Description: This indicator assesses the condition or degree of stability, which can be a clue of probable sustainability of natural resource uses in mountain areas. Another purpose of the indicator is to identify obvious land degradation and misuses that need policy responses in order for mountains to be returned to sustainable use.
Scope: Regional
Unit of measurement: The first two indicators relate to land use or misuse and can be measured in hectares of land area and expressed as the percentage of a mountain area. The last indicator measures yields of natural resource products (fuelwood, timber, wildlife food, nonwood forest products, and so forth) that can be expressed in dollars, grain equivalent unit, or other values and compared to the replacement of these products in terms of reproduction and growth.
Targets: Chapter 13 of Agenda 21 establishes objectives for sustainable development related to land productivity and appropriate use. The indicator is suitable for the setting of local targets. In some cases it can relate to national targets for forestry and land use.
Methods of measurement: For the subindices on soil protection, hazard zones, and degraded areas, many of the measurements of vegetation, soils, and land uses are standard procedures that draw on sources such as remote sensing, existing maps, geographic information system (GIS) databases, field observations, and so forth, to assess land use conditions. Forest assessment data and soil surveys, for example, may be used. Some of the measurements, such as identification of landslide hazard areas, are somewhat more specific but use the same measurement techniques. The subindex on productivity takes volumetric units for yields of natural resource products (fuelwood, timber, wildlife food, nonwood forest products). This may also be converted to a standard unit of value, for example, to dollars or a grain equivalent type unit.
Limitations: Often data are not readily available for mountain areas and may need to be collected. Productivity is a complex measurement to standardize. Surveys for productivity, if based on interviews, are subject to bias. The rationale for this index and its aggregation has its limitations and may not apply to all countries. Attempts to extrapolate data into mountain areas are not advisable. Hazard zones, such as landslide areas, require techniques specific to mountain areas.

Pillar: Security
Indicator: National monthly rainfall index

Description: The national average of monthly station rainfall, weighted by the long-term station rainfall average
Scope: National, but could be adapted to regional
Unit of measurement: The preferred measure is the departure from average in standard deviations. An alternate measure is the absolute value or departure from the average in millimeters.
Methods of measurement: Indicator is computed from monthly station rainfall data
Limitations: Most dryland ecosystems transcend national boundaries. Intra-seasonal patterns (such as bimodal rainfall) are not taken into account. The quality of the indicator depends on the number and geographic distribution of suitable rainfall stations.

Pillar: Protection
Indicator: Irrigation percent of arable land
Description: Land area under irrigation as a percentage of total arable land area
Scope: National, regional
Unit of measurement: Percent
Targets: The indicator can lend itself to the establishment of national targets. It relates to targets for global, regional, and national food security.
Methods of measurement: Irrigated area (area equipped with hydraulic structures) divided by arable land.
Limitations: There are conceptual and methodological difficulties of interpretation. Some national data use a narrow definition while other data may be broadly defined. Some countries report areas with irrigation facilities, while others use areas provided with water. The indicator value does not capture the quality or conditions of either land or water resources. Knowledge of other factors such as crops grown, agroecological zone type, and distribution of farm size would be relevant to its interpretation. Other aspects of irrigation, including equity, efficiency, and importance to the overall national agricultural production are not reflected in the indicator. The indicator does not provide a measure of lands with irrigation potential.

Indicator: Wood harvesting intensity
Description: The indicator compares the total forest fellings as percentage of net annual increment. In other words it compares the amount of yearly (or other time period) harvested wood or any other forest product with the annual increment from the forest. If annual increment is not known, allowable cut can be used as a surrogate.
Scope: Regional
Unit of measurement: Percent
Targets: In general the target would be set by the sustained yield principle. Several countries have calculated their total annual allowable cut, or total annual increment, and their total annual removals. Most developed countries are harvesting between 70 to 80 percent of the total annual increment of their forests. Targets still need to be established for tropical forests.
Methods of measurement: The enumerator is total annual roundwood production. The denominator is total annual productive forest increment. An adequate time series is required to show meaningful trends. For tropical natural forests where no data is available on the forest annual increment or where the harvested wood comes only from a few species, an adjustment is proposed that relates annual production to the total standing volume of the forest and the average rotation cycle applied in a country for a given reference year; for example, 120 years for teak forests in Burma.
Limitations: The indicator is related to timber production. It does not relate to nonproductive land from a forestry perspective. It has implications for other forest resources, but an indicator considering all values of forest ecosystems would be more appropriate from a sustainable development perspective. For the present indicator reliable data are only available from a minority of

countries, mostly developed, and for plantations. However research data on the annual increment of tropical natural forests are improving, and it is expected that sufficient data and estimates should become available during the coming years.

Indicator: Forest area change
Description: The amount of natural and plantation forest area tracked over time
Scope: Regional

Unit of measurement: Hectares (ha)
Methods of measurement: The measurement methods for forest area can be contained in national forest inventories and obtained by sampling ground surveys, cadastral surveys, remote sensing, or a combination of these. The forest area is calculated as the sum of plantations and natural forest areas with tree crown cover equal to or more than 10 percent. This calculation is made at given reference years as follows:

The deforestation rate (DR) is the compound annual rate in percent from year P to year N.

Limitations: The area figure does not give any indication of the quality of the forest, its ecosystem context, or forest values or practices. The indicator does not provide information on the degradation of the forest resources in a country. The total forest area in a country might remain unchanged, but the quality of the forest can become degraded. Due to the definition used, the indicator covers a very diversified range of forests ranging from open tree savannah to very dense tropical forests.

Indicator: Area affected by salinization and waterlogging
Description: Total area affected in hectares compared to the total land area
Scope: Regional
Unit of measurement: Ha and percent
Methods of measurement: The indicator is computed as the land that is lost to salinization and waterlogging such that it cannot be cultivated. The data is directly derived from official national sources.

Indicator: Threatened species as a percent of total native species
Description: Number of species at risk of extinction in proportion to the total number of native species
Scope: National, regional
Unit of measurement: Percent
Methods of measurement: Select all classes for which numbers of native species are known (or estimated) and whose status is monitored or assessed from time to time. For each class calculate the percentage of threatened native species against total native species in this class.
It is recommended to report on four subindicators:

1. Percent threatened vascular plant species, total all classes
2. Percent threatened species within each vascular plant class
3. Percent threatened vertebrate species, total all classes
4. Percent threatened species within each vertebrate class.

Limitations: It is possible to monitor only the more conspicuous and well-known species, which make up a small proportion of total species diversity. Genetic variation within some species may be as important as differences between species, but may be missed by reporting at the species level alone.

Indicator: Emissions of greenhouse gases (GHG)
Description: National anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)

Scope: National
Unit of measurement: Annual emission levels in gigagrams (Gg) of CO_2 equivalents; methane and nitrous oxide emissions are converted into CO_2 equivalents by using global warming potentials (GWP); annual percentage change in total GHG emissions beginning with 1990 as base year would provide trends and rate of change in emission levels for each Party to the Climate Change convention.
Methods of measurement: Emissions for CO_2, CH_4, and N_2O are estimated based on activity data from fuel combustion, fugitive fuel emissions, industrial processes, solvent use, agriculture, land use change, and forestry and waste. Emission levels are calculated using factors associated with each gas and relevant activities. A greater degree of international comparability has been achieved by using default emission factors proposed by the Intergovernmental Panel on Climate Change (IPCC). National emission factors have been used, whenever available, which has resulted in increased precision in national GHG emissions.

Proposed additional related indicators would include annual GHG emissions per capita and annual GHG emissions per unit of GDP.

Indicator: Emissions of sulphur oxides
Description: National anthropogenic emissions of sulphur oxides (SO_x) expressed as amounts of sulphur dioxide (SO_2)
Scope: National
Unit of measurement: Tonnes or 1000 tonnes; percentage change in emissions over time (for example, percentage change in emissions between 1980 and 1995) Proposed denominator: Per capita, per unit of gross domestic product (GDP), per unit of gross energy consumption
Methods of measurement: In some rare cases emissions are known by direct measurements in stacks or by material balances. Generally, sulphur oxide emissions are calculated with the help of emission factors that reflect the presence of sulphur compounds in different types of fuels and other products:

Emission = Emission factor x Activity level.

Emission factors for stationary sources should be disaggregated by fuels, facilities, or economic sectors. They should include power stations (gas, oil, and coal); industrial processes (pollutants emitted in manufacturing products from raw materials); nonindustrial fuel combustion; and other stationary sources (waste treatment and disposal, sewage treatment, agricultural activities, and coal refuse burning). Emission factors for mobile sources should be disaggregated by fuels and types of vehicles. They should cover road traffic (passenger cars, light and heavy duty trucks, buses, coaches, and motorcycles) and other mobile sources (navigation, railways, air traffic, and agricultural equipment).

Since the objective of the set of indicators is to describe the impact of human activity on the environment, emissions from natural sources (such as forest fires and volcanic eruptions) should be excluded.

Indicator: Emissions of nitrogen oxides
Description: National anthropogenic emissions of nitrogen oxides (NO_x) expressed as amounts of nitrogen dioxide (NO_2)
Scope: National
Unit of measurement: Tonnes or 1,000 tonnes; percentage change in emissions over time (for example, percentage change in emissions between 1980 and 1995). Proposed denominator: Per capita, per unit of gross domestic product (GDP), per unit of gross energy consumption
Targets: Within the framework of the Convention on Long Range Transboundary Air Pollution (Geneva, 1979), a protocol to reduce nitrogen emissions to their 1987 level by 1995 (Sofia, 1988) entered into force in 1991.

Methods of measurement: In some rare cases emissions are known by direct measurements in stacks or by balance of material. Generally, nitrogen oxide emissions are calculated with the help of emission factors that reflect the presence of nitrogen compounds in different types of fuels and other products:

Emission = Emission factor x Activity level.

Emission factors for stationary sources should be disaggregated by fuels, facilities or economic sectors. They should include power stations (gas, oil, and coal); industrial processes (pollutants emitted in manufacturing products from raw materials); nonindustrial fuel combustion; and other stationary sources (waste treatment and disposal, sewage treatment, agricultural activities, and coal refuse burning). Emission factors for mobile sources should be disaggregated by fuels and types of vehicles. They should cover road traffic (passenger cars, light and heavy duty trucks, buses, coaches, and motorcycles) and other mobile sources (navigation, railways, air traffic, and agricultural equipment).

Since the objective of the set of indicators is to describe the impact of human activity on environment, emissions from natural sources (such as lightning) should be excluded.

Pillar: Viability
Indicator: Population living below poverty line in dryland areas
Description: A measure of the number of persons/households classified as living below the nationally defined poverty line, given as a fraction of the total population in a country's dryland area
Scope: National
Unit of measurement: Percent
Methods of measurement: A country-specific poverty line. The headcount index as a percentage of the population is established. The headcount index is the percentage of the population below the poverty line. This needs to be computed at a regional or subregional level to cover the dryland area, depending on the country.
Limitations: The concept of a poverty line can be misleading. Poverty is measured in terms of income. However, populations in dryland areas may be income-poor given lack of access to markets or monetized economies, but wealthy in terms of livestock. Also, the poverty line measurement is insensitive to the distribution of income below the poverty line. Security of tenure, a key socioeconomic aspect of sustainable development in drylands, is not reflected in poverty indicators. Therefore while the issues of poverty and population pressure are important in combating desertification, further refinement of the indicator is necessary. Georeferencing to agroecological conditions and crops, and knowledge of carrying capacity and its spatial/temporal variability, is needed to properly capture the role of poverty in the degradation of drylands. Disaggregation of poverty data by dryland may not be readily available.

Indicator: Use of agricultural pesticides
Description: Use of pesticides per unit of agricultural land area
Scope: Regional
Unit of measurement: Pesticide use in metric tons of active ingredients per 10 km2 of agricultural land
Methods of measurement: Data on pesticide use are usually derived from sales or "domestic disappearance" and expressed as active ingredients. Agricultural area data are widely available. Interpretation will benefit from information on types of active ingredients in use, seasonal doses, rate of application, and variability on use for different crops and regions.
Limitations: This indicator provides an aggregation that ignores toxicity, mobility, and level of persistence, as well as spatial and application variances. It does not consider the use of pesticides

outside of agriculture, which can be significant in developed countries. Data omissions and errors often occur during the transfer of the primary data to statistical authorities.

Indicator: Use of fertilizers
Description: Extent of fertilizer use in agriculture per unit of agricultural land area
Scope: Regional
Unit of measurement: Metric tons of fertilizer nutrients per 10 km2 of agricultural land

Targets: Targets should be based on national situations
Methods of measurement: Data on fertilizers are compiled from industry sources and nontraditional sources. Data for developing countries generally refer to domestic disappearance based on imported products. The derived figures in terms of nutrients are then divided by the agricultural land area.
Limitations: Environmental impacts caused by leaching and volatilization of fertilizer nutrients depend not only on the quantity applied, but also on the condition of the agroecosystem, cropping patterns, and farm management practices. In addition this indicator does not include organic fertilizer from manure and crop residues or the application of fertilizers to grasslands. Reliability of fertilizer data is questionable. The indicator assumes even distribution of fertilizer on the land.

Indicator: Energy use in agriculture
Description: The energy utilized in agriculture on a yearly basis expressed as a ratio of energy inputs and agricultural production, as well as in absolute terms
Scope: National, regional
Unit of measurement: Joules per ton of agricultural products
Methods of measurement: Annual energy inputs for each stage in agricultural production and processing are determined and converted into equivalent units such as terajoules (TJ) and aggregated as total energy. Annual agricultural production figures are collected for all products. The obtained values are then compared for the same year and can be tracked over time to see how changes in both terms affect their ratio.

Pillar: Acceptability
Indicator: Decentralized local level natural resource management
Description: This indicator represents the extent to which resource management is in the hands of landholders or other de facto local resource controllers, and partially represents whether local resource controllers and others with direct impact on resources have incentives to conserve them.
Scope: National
Unit of measurement: Numbers of local governments and local communities to which resource management has been devolved or with which resource management is shared as percentages of total numbers of local governments and local communities
Methods of measurement: Rights and responsibilities devolved; total number of local governments/communities; number of local governments/communities to which rights or responsibilities have been devolved; capacities of all concerned to work to a decentralized model; actors involved in sharing resource management, and manner and extent of that sharing. Measurement is complicated by the facts that more than one local level may be involved and that devolution of management includes several aspects, including responsibilities, rights to rewards, skills, and information. Consequently the indicator may entail several measurements.
Limitations: The indicator requires development and testing. Devolution says nothing about the capacity of the various partners to work together according to a decentralized model. The measurement unit ignores the important qualitative assessment of how well resource management is shared among resource users, local communities, and higher levels of government. The indicator does not show whether local communities and governments actually conserve the resources.

Indicator: Agricultural education
Description: Public expenditure on agricultural education (both secondary and post-secondary schools that teach agriculture) reflecting national investment in human capital for sustainable agricultural and rural development (SARD)
Scope: National
Unit of measurement: Percent of gross domestic product (GDP)

Targets: Both the United Nations Educational, Scientific, and Cultural Organisation (UNESCO) and the World Bank have established international targets for investing in education.
Methods of measurement: The indicator is calculated from current public expenditure on agricultural education as a percentage of GDP measured in US$.
Limitations: The indicator does not reflect the quality of the education provided. It is assumed that there is a relationship between the level of investment and the quality of educational services.

Indicator: Managed forest area ratio
Description: Proportion of the total forest area covered by officially approved and actually implemented forest management plans
Scope: National, regional
Unit of measurement: Percent
Targets: At the international level targets have been established for tropical forests, namely the International Tropical Timber Organization (ITTO) Target 2000. Some countries have set national targets.
Methods of measurement: Compilation of the aggregate area for forest management plans to provide the total managed forest area, divided by the total forest area
Limitations: The indicator only shows the extent of forest management. It says nothing about the quality of plan implementation against sustainable development objectives. No internationally accepted operational definition of sustainable forest management exists, although work is in progress under the aegis of the Intergovernmental Panel on Forests. Although many guidelines on sustainable forest management exist, there are only a few agreed minimum sets of essential elements of sustainable forest management at the regional level and none yet at the global level. Total forest area in some countries would include some forest area that will never be productive from a forestry viewpoint and thus probably not subject to management plans, unless for purposes other than forestry.

Indicator: Protected forest area as a percent of total forest area
Description: The definition of a protected area is an area of land or sea especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources and managed through legal or other effective means (International Union for Conservation of NatureIUCN).
Scope: National
Unit of measurement: Percent
Targets: Guidelines for the classification and establishment of protected areas are available from IUCN. Many countries have established guidelines for protected areas suited to their national situation.
Methods of measurement: The measurement compares the amount of protected forest area to the total forest area as a percent.
Limitations: The indicator is limited to forest ecosystems. It does not provide information on the ecological value of the protected areas. A country can set aside large areas of forests with a low importance for biological diversity and continue to unsustainably harvest highly valuable unprotected forests. The indicator says nothing about the effectiveness of the protection; either from the viewpoint of ecological representivity or that of management and law enforcement. Ideally the protected forest area should cover representative examples of all existing forest ecosystems.

with the area appropriate to their rarity or uniqueness. The indicator does not in itself provide information on the degree of protection, including the range of allowable uses.

Indicator: Protected land area as a percent of total land area; and protected marine area as a percent of total marine area
Description: This indicator combines the area of protected land (including freshwater areas), expressed as a percentage of the total land (and freshwater area, and the area of protected marine area, expressed as a percentage of the total marine area.

Scope: National, regional
Unit of measurement: Percent
Targets: The 1991 report "Caring for the Earth: A Strategy for Sustainable Living" establishes a target of 10 percent protected area for each major ecological region of countries by the year 2000. A similar target was agreed to by the IV World Congress on National Parks and Protected Areas in 1992. Both targets reflect recognition that representation of ecosystem diversity is more meaningful than a flat percentage of the country's area.
Methods of measurement: The usefulness of this indicator depends on clearly distinguishing totally protected areas and partially protected areas, since they have different, although complementary, functions. Each requires a separate expression of the indicator as follows: (a) calculate the combined area of totally protected areas of 1,000 ha. or more; (b) calculate the combined area of partially protected area regardless of size; (c) calculate the percentage of the total land/marine area occupied by each group.
Limitations: The effectiveness of this indicator is limited by two problems. First, it represents de jure, not de facto, protection. It does not indicate the quality of management or whether the areas are in fact protected from incompatible uses. Second, the indicator does not show how representative the protected areas are of the country's ecological diversity. This is a significant deficiency, since a large proportion of some ecosystems may be protected to the neglect of others.

KEY WORDS: Productivity, protection, security, viability, acceptability, soil quality, rainfall, inputs, resource management, irrigation, forestry, emissions, biodiversity, education level, population under poverty level

CSD. 1996b. "Work Programme on Indicators of Sustainable Development of the Commission for Sustainable Development." Commission for Sustainable Development, United Nations Department for Policy Coordination and Sustainable Development, New York, New York. World Wide Web http://www.un.org/dpcsd/index.html.

NOTES: Objective of work program is to make indicators for sustainable development accessible to decisionmakers at the national level by defining them, elucidating their methodologies, and providing training and other capacity-building activities, as relevant. The current role of the Department for Policy Coordination and Sustainable Development, as task manager of this issue, is to bring together the many actors in this field to build on their work and to propose a cooperative programme for indicators for sustainable development that may directly serve the needs of the Commission on Sustainable Development, as well as all member states.

The program proposes a menu of indicators for use by decisionmakers in monitoring progress at a national level towards sustainable development through the implementation of Agenda 21. However a desire for international consistency calls for the development of standardized concepts, definitions, and classifications.

Driving force-state-response framework (formerly referred to as pressure-state-response).

Driving force indicators indicate human activities, processes, and patterns that impact on sustainable development.

State indicators indicate the state of sustainable development.

Response indicators indicate policy options and other responses to changes in the state of sustainable development.

Menu is grouped in categories covering the social, economic, environmental, and institutional aspects of sustainable development.

Still compiling and determining indicators; entering a phase of monitoring the use of indicators in a few selected countries (until late 1997). Further work on development of indicators expected to continue for some time.

CSD Working List of Indicators of Sustainable Development

In driving force-state-response format broken down into social, economic, environmental, and institutional aspects of sustainable development

KEY WORDS: Indicators (general)

Dalton, T.J. and Masters, W.A. Unpublished. "Soil Degradation, Technical Change, and Government Policies in Southern Mali." World Bank, Washington, D.C. 15 pp.

ABSTRACT: This study links intertemporal optimization to a biophysical crop-growth model, finding that agricultural intensification does not dramatically degrade soils in southern Mali. Productivity growth can be sustained through adoption of new techniques, particularly with policy reforms to reduce marketing costs and tax the use of common-property resources.

NOTES: This study uses new modeling tools to address the sustainability of technical change in a key agroecological region of West Africa. The authors link a detailed biophysical model of crop growth to a dynamic model of household behavior to stimulate farmers' choices and their consequences over time.

The key findings are that new farming methods in the Sudano-Guinean region of Southern Mali, where rapid intensification has disrupted traditional agropastoral systems, are far more sustainable than many observers have argued and that additional productivity growth can be sustained with supportive government policies. Key interventions include providing agricultural research, maintaining low marketing costs, and imposing pasture taxes to account for the cost of grazing in common areas.

KEY WORDS: Protection, viability, soil management

Dumanski, J.1994. *International Workshop on Sustainable Land Management for the 21st Century: Summary.* Workshop Proceedings. Agricultural Institute of Canada, Ottawa, ON. 50 pp.

NOTES: The objectives for the Lethbridge workshop were to investigate the complexities of issues involving SLM and how to integrate these into a comprehensive, practical, and field-useable framework for evaluation; to develop indicators and criteria for evaluation of SLM systems; and to formulate recommendations for research and technology transfer in SLM.

The conclusions of the focus groups were as follows: First, no single indicator for SLM can be developed, and a basket of indicators is the preferred approach; second, to be truly effective indicators must be tailored to reflect the land uses, management practices, and environment (soil, climate, and market) where they will be applied. Nevertheless, there were several indicators that consistently reappeared from several focus groups. These indicators possibly preview a set of generic indicators that could be developed as international standards for evaluating and monitoring of SLM. They are:

Crop yield (trend and variability)

Nutrient balance

Maintenance of soil cover

Soil quality/quantity

Water quality/quantity

Net farm profitability

Use of conservation practices.

These indicators will require some local manipulation for specific uses in specific environment, but they provide a good starting point for further development.

KEY WORDS: Indicators (general), sustainable land management, productivity, security, protection, viability, acceptability

Dumanski, J. de Jong, R. and Brklacich, M. 1996. "Changes in Crop Yield and Variability as Indicators of Sustainable Land Management," pp. 36 in Stushnoff, C.T., ed. *Proceedings of the Second Sustainable Land Management Workshop*, University of Saskatchewan, 20 February 1996. Agriculture and Agri-Food Canada, Saskatoon, SK. 29 pp.

SUMMARY: Information on yield performance over time is fundamental to an evaluation of sustainability in farming systems. Crop yield and variability are two of the five important criteria for sustainable land management and thus must be included in any evaluation of sustainability. The results of the Lethbridge workshop on sustainable land management for the 21st century (Dumanski, 1994) also identified crop yield and variability as basic indicators of sustainability.

Average crop yields are often used to assess yield performance, but this is not useful for evaluating sustainability because average yields represent a long-term norm, but provide no information on performance changes over time. Sustainability requires information on yield trends to assess whether yields are stable or increasing and thereby contributing to sustainability, or whether they are negative and thereby signalling probable failure. Further information is required on trend in yield variability, to assess whether the risk of crop production is stable, increasing, or decreasing.

Trends in yield and variability (risk) do not change synchronously. The best situation occurs when yields are increasing and variability is decreasing; this is a strong signal that crop production technologies are contributing to sustainability. Conversely, if yields are decreasing and variability is increasing, then obviously the system will fail, probably in the not-too-distant future.

Pillars: Productivity, security
Indicator: Yield performance
Description: A composite indicator encompassing average crop yield and trend in yield variability
Crop: Wheat, canola
Location: Saskatchewan
Scope: Local, regional
Unit of measurement: Average crop yield (kg/ha/yr)
Trend in yield variability (percent)
Method of measurement: Average annual yields and coefficients of variation are calculated for each area. These values are then used to calculate long-term means and yield trends.

KEY WORDS: Productivity, security, yield performance

Eilers, R.G. Eilers, W.D. and Fitzgerald, M.M. 1996. "Soil Degradation Risk Indicator: Soil Salinity Risk Component." Report 16. Environment Bureau, Policy Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 24 pp.

ABSTRACT: Agricultural land use can impact the sustainability of inherent soil quality by its influence on the extent, severity, and dynamics of soil salinity. To assess this impact a salinity risk index (SRI) was developed and applied to the agricultural region of the Canadian prairies utilizing land use data sets for 1991 and 1981. The analysis, presented in map form, shows the current status of dryland salinity for 1991, the current risk based on land use in 1991, and an analysis of the change in risk due to the change in land use from 1981 to 1991. The total extent of moderate or more severe salinity (ECe>8 dS/m) for the prairie region, as determined from a summation of each provincial extent map, is 1.4 million ha. This area is depicted on a small scale extent map. The risk assessment using 1991 land use data indicates that 62.2 percent of the farm land has little to no risk of a change in salinity, 27.9 percent has a moderate risk, and only 9.9 percent of the land has a high risk. A comparison of the risk index classes for the 1981 and 1991 land use data indicates that risk of salinity for the majority of the land (92 percent) has not changed, whereas less than 7 percent of the land has a lower risk class and approximately 0.5 percent has a higher risk class in 1991. These data are not presented in the context of trends but simply as observations at two points in time.

The report proposes that this approach could be utilized periodically in the future to track impact of changes in land use on a landscape basis and thus serve as an indicator of agrienvironmental sustainability. This information will be utilized by upper levels of government to target programs and agricultural policy.

NOTES:
Pillar: Protection
Indicator: Soil salinity risk
Description: Assesses the risk for changing the status of soil salinity
Scope: Regional, local
Soil: Dryland soil salinity
Location: Canadian prairies
Unit of measurement: Dimensionless index, grouped into three classes of risk, low, moderate, and high
Methods of measurement: The Salinity Risk Indicator (SRI) consists of five components: the presence of salinity in the landscape, topography, soil drainage, aridity, and land use.

The SRI is based on the premise that (a) functional relationships exist among the various components, which affect the process of salinization; (b) these components can be given a relative numerical weighting for their influence; and (c) each of these weightings can be combined in a simple multiplicative relation resulting in a dimensionless numerical value, which will be utilized as an index of salinity risk. Comparison of the index values for different map polygons will enable comparisons of relative potential for change.

Specific emphasis has been given to assessing the role of land use as a dynamic component of the risk index. The land-use factor will be utilized to predict the trend for potential impact of agricultural practices on the long-term susceptibility (risk) to changing salinity.

Limitations: Scientific opinion-based (requires a collective effort), not quantitative

KEY WORDS: Protection, soil salinity

Environmental Indicator Working Group. 1995. "Description of Indicators and Project Activities and Outputs to 1998." Report 10. Environment Bureau, Policy Branch, Agriculture and AgriFood Canada, Ottawa, ON. 11 pp.

NOTES:

The Agri-Environmental Indicator (AEI) Project of Agriculture and Agri-Food Canada was initiated in 1993 to identify potential AEIs for Canadian agriculture. In December 1993 a national consultation was held with stakeholder groups to review and prioritize agri-environmental issues and potential indicators for each. Twelve AEIs were selected and development work was initiated. A second national consultation was held in February 1995, resulting in the integration of the twelve AEIs into a smaller number of indicators and their components. These were subsequently linked to corresponding issues and performance objectives. Each indicator is at various stages in development. See Banerjee (1996) for a description of indicators under development.

KEY WORDS: Indicators (general)

FAO. 1996. "A Programme to Develop Land Quality Indicators at Sub-National, National, and Global Scales." Food and Agriculture Organization, Rome. World Wide Web http://www.fao.org/ waicent/faoinfo/sustdev/EPdirect/EPre0027.htm

NOTES:

The LQI program is being developed to better harmonize the combined objectives of production and environmental management and to ensure more sustainable use of land, water, and biological resources. It is one of several important responses to the major challenges put forward by UNCED in Agenda 21. Although the program is being initiated through a coalition of international agencies, including the World Bank, FAO, UNDP, and UNEP, the task is too important for any one agency or group. Additional partners are actively being solicited for the program.

LQIs are needed to address major land-related issues of national and global significance, such as land-use pressures, land degradation, and soil and water conservation, as well as policy-related questions on sustainable land management. Once developed and harmonized through international scientific protocols, LQIs will be used for policy and program formulation for district, national, and global assessment; environmental impact monitoring; and to promote technologies, policies, and programs to ensure better use of natural resources and sustainable land management.

The Pressure-State-Response (PSR) Framework has been adopted as the common approach for the program. The framework infers that human activities, including land management changes caused by population pressures, exert pressures on the land resource, resulting in a change in the state (quality) of the land. Knowledge of this triggers responses to mitigate against the pressures and the change in land.

Objective of program:

The program will initially focus on LQIs for developing countries, although some experimental work will be done in other regions. The objectives of the program are:

1. To develop a set of harmonized LQIs for managed ecosystems (agriculture and forestry) in the major Agro-Ecological Zones (AEZs) of tropical, subtropical, and temperate environments

2. To identify sources of data and information and develop common methods for analyses, aggregation, and application of the results

3. To validate and disseminate the findings among the major institutions responsible for collection of LQI data, and to reinforce the institutional capacity needed for setting and implementing land and natural resources priorities, policies, and technologies at subnational and national levels.

Outputs:

1. A set of harmonized LQIs to be used by decisionmakers and appropriate to major policyrelated questions on land management in tropical, subtropical, and temperate regions. LQI Source Tables will be prepared for each country and locally updated.

2. A set of appropriate targets and thresholds for the state LQIs to provide guidance toward more sustainable land management for the different ecoregions.

3. A metadata information system on land-related information set up on the WWW, and available as stand-alone systems as well.

4. Assessments of trends in land quality for various AEZs for use at subnational and national level, leading to global assessment of the condition of land as a function of its use.

KEY WORDS: Land quality, indicators (general)

Gallopin, G.C. 1994. "Agroecosystem Health: A Guiding Concept for Agricultural Research?" pp. 5165 in Nielsen, N.O., ed. *Proceedings of an International Workshop: Agroecosystem Health*, Ottawa, ON, 9 June 1994. University of Guelph, Guelph, ON. 114 pp.

CONCLUSION: The concept of agroecosystem health seems to be potentially useful in guiding agricultural research on sustainable agriculture and poverty alleviation in the CGIAR. However, there is a need to differentiate agroecosystem health from agroecosystem sustainability. Both are multidimensional, and both embody value judgements. There is no general agreement yet on what constitutes sustainability, even when neglecting consideration of the social and economic dimensions of the concept, and even less on what constitutes ecosystem health.

As proposed here, health could be profitability conceived of as the underlying foundation of sustainability (for example, the internal properties of the system that makes it sustainable within a range of environmental conditions). Actual persistence of the system will depend also on its external environment, and an intrinsically sustainable system may crash under extreme external conditions in the same way a healthy person may die in a car accident.

One of the useful avenues of research could be to explore to what extent the "ecosystem stress syndrome" can be applied to managed ecosystems such as agroecosystems, and determine which are the human dimensions of the syndrome. However the degree to which the concept of agroecosystem health can become the much-needed framework for "an acceptable research model which embraces the physical, biological, and human dimensions of long-term sustainability" is much less clear. It might well be that the concept is much more useful as a metaphor suggesting more systematic approaches to the diagnosis and treatment of agroecosystem ills, underscoring the importance of validation of remedial action interventions, drawing attention to the inherent subjective nature of health assessments, and providing a language in which the concern for ecosystem health becomes a natural extension of the concern for individual health.

The ambiguity of the concept of ecosystem (and, by extension, agroecosystem) health gives it some of its richness; that which attempts to transform it into a rigorous and specific scientific tool or accepted research model may well strip it of the intuitive, general meaning that is its chief value.

KEY WORDS: Indicators (general). Framework for the Evaluation of Sustainable Land Management (FESLM), sustainable land management

Gameda, S. 1996. "Farmer Knowledge and Sustainable Land Management," pp. 1012 in Stushnoff, C.T., ed. *Proceedings of the Second Sustainable Land Management Workshop*, University of Saskatchewan, 20 February 1996. Agriculture and Agri-Food Canada, Saskatoon, SK. 29 pp.

NOTES:

Farmers are faced with a variety of critical sustainability considerations and implement numerous strategies to address the issues arising from these considerations. This study focuses on identifying the common characteristics in farmer strategies that make their production systems sustainable. This approach to identifying sustainable land management (SLM) characteristics of different systems recognizes the diverse ways of achieving sustainability within a given region. Commonalities in the characteristics of each sustainable farming system can serve as indicators of SLM. Moreover, they can be distilled for use as guides for other producers who wish to achieve sustainability in their farming practices. A focus on common SLM characteristics avoids limitations of standard prescriptive approaches that put emphasis on a narrow set of farming practices. Thus for each sustainability characteristic or indicator, producers would have a wide variety of choices as to what practices to implement within the context of their regional constraints and their management preferences.

Pillar: Productivity
Indicators:
High input: Soil fertility trends
Crop yield response
Availability of labor
Moderate input: Yield trends
Adoption of new technologies and techniques
Crop variety availability and performance
Organic: Length of rotation
Weed management
Crop variety availability and performance

Pillar: Security
Indicators:
High input: Economic status
Yield trends
Weather trends
Moderate input: Time required in mastering new techniques
Catastrophic weather/weather trends
Organic: Resource potential of land
Soil moisture at seeding
Weather trends

Pillar: Protection
Indicators:
High input: Degradation risk
Extent of crop cover
Moderate input: Degradation trends
Length of rotation
Extent of fallow
Organic: Degradation trends
Crop yield trends

Pillar: Viability
Indicators:
High input: Cash flow/revenues
Presence of livestock
Management objectives
Moderate input: Cash flow/revenues

Government programs
Management objectives
Organic: Organic market demands
Extent of value added
Availability of labor

Pillar: Acceptability
Indictors:
High input: Personal and family health
Viability of farming
Moderate input: Availability of services
Off-farm impacts
Organic: Public awareness of organic farming
Viability of farming
Age level of community

KEY WORDS: Framework for the Evaluation of Sustainable Land Management (FESLM), productivity, security, protection, viability, acceptability

Gameda, S. and Dumanski, J. 1995. "Framework for Evaluation of Sustainable Land Management: A Case Study of Two Rain-fed Cereal-Livestock Farming Systems in the Black Chernozemic Soil Zone of Southern Alberta, Canada." *Canadian Journal of Soil Science* 75:4, 429-37.

ABSTRACT: The Framework for Evaluation of Sustainable Land Management (FESLM) was used to assess the sustainability of two land-use systems in the Canadian prairies. The FESLM provided a means of identifying the factors impacting on sustainability, the processes by which these factors operate and interact, and the indicators and thresholds by which they could be measured to attain an assessment end point. On the basis of the framework it was possible to expand sustainability assessment beyond traditional factors of productivity and economic viability to include ones pertaining to production risk, protection of the natural resource base, and social acceptability. Also, the decisionmaking characteristics of the producer were identified as important components of sustainability. Preliminary indications are that substantially greater amounts of farm-specific and regional data are required to make a conclusive FESLM-based sustainability assessment. Nevertheless, application of the framework suggests that, for the farming systems and the type of producer under consideration, the conservation-based land-use system is more sustainable than the conventional land-use system.

NOTES:

Purpose of study was to test the FESLM methodology for evaluation of actual farming systems. Study shows it is possible to expand sustainability assessment beyond a focus on productivity and economic viability, to include pillars pertaining to production risk, protection of the natural resource base and social acceptability.

Key finding: Decisionmaking characteristic of producer is important social indicator. Examples include membership in conservation clubs, on-farm experimentation, responsive management style, and rapid adjustment to changing conditions.

Soil: Black chernozemic

Crops: Canola, barley

Production method: Conventional and conservation (comparison)

Region: Southern Alberta, Canada

Indicators:

The status of indicators used in the case studies under conventional and conservation production systems

Indicator	*Status* *Conventional*	*Conservationa*
Physical		
Percentage of land in fallow	2030%	<10%
Method of fallow	Tillage	Tillage + chemical; chemical
Depth of soil moisture at seeding	Weather dependent	Improved with increased stubble height
Percentage and trends of degradation	Entire farm experienced erosion 3-year period	Erosion eliminated, salinity stable
Type of tillage practice	Conventional	Minimum, zero
Biological		
Changes in fertilizer and pesticide use	According to standard rates for region	Increased over conventional use
Length and diversity of rotations	3-yr, low diversity	3-yr, more legumes and forages
Crop yield trends	Variable	Variable
Economic		
Trends in cost of production	Increasing costs, reduced returns	Reduced fuel costs, increasing returns with production of specialy crops
Gross margin	Decreasing ($30/ha in 1991)	Improving ($41/ha in 1991)
Number and types of govt programs	Crop Insurance	Crop Insurance
Farmer's management objectives	Risk reduction, profit maximization	Risk reduction, profit maximization
Social		
Distance to services	50 km	50 km
Social perceptions of conservation	Favoured conventional tillage. Some concern regarding use of pesticides	Increased acceptance of conservation
Reasons for participation in government programs	Risk reduction, income stabilization	Risk reduction

a. Adopted in 1986, with gradual shift to minimum tillage, snow management and straight combining, finally to zero tillage by 1993.

Limitations: Preliminary indications are that substantially greater amounts of farm-specific and regional (contextual) data are required to make a conclusive FESLM-based sustainability assessment.

KEY WORDS: Framework for the Evaluation of Sustainable Land Management (FESLM), productivity, security, protection, viability, acceptability

Group for Development and Environment. 1995. "Sustainable Use of Natural Resources: A Conceptual Approach to Sustainable Management of Natural Resources in the Context of Development." Development and Environmental Report 14. Institute of Geography, University of Berne, Berne, Switzerland. 46 pp.

NOTES:

This report presents a conceptual approach to a central aspect of sustainable development: sustainable use of natural resources. It is addressed primarily to specialists at Swiss Development Cooperation, but will also be of interest to others concerned with development questions or specific issues related to sustainable resource use.

The conceptual approach is intended as a general guideline. It is not a blueprint for concrete planning, execution, and evaluation of projects. Rather its purpose is to stimulate and enhance public discussion about questions of resource use. It is elaborated in the three main parts of the report.

The first part defines natural resources as components of nature that are of use to human beings. Resource use always reflects a particular social situation, and it changes in relation to space and time. No universal conclusions can be drawn about sustainable resource use. Each society must decide for itself what constitutes sustainable use of natural resources, because sustainability is primarily a question of evaluation.

The second part is concerned with the central features of this evaluation and with the process of public discourse. Included are discussions of internal and external participation, the institutionalization of public discourse, and empowerment of disadvantaged social groups. Development organizations take part in public discussions about resource use and have a dual role to play; they advance their own aims and ideas while also supporting the process of public debate over sustainability.

The third part of the report deals with other key aspects of sustainable resource use. It addresses the participation of women as an essential prerequisite of sustainability; the question of long-term access to resources as an important criterion for distinguishing between normal use and over-exploitation; multifunctionality; and biodiversity as a significant indicator of sustainable systems of resource use.

KEY WORDS: Sustainable land management

GTZ. 1995. *Indicators for Sustainable Land Management for Use in Development Projects: Basic Concepts.* Indicators for Sustainable Soil Management Pilot Project-PN 95.9203.1. Deutsche Gesellschaft fur Technische Zusammenarbeit GmbH (GTZ), Eschborn, Germany.

NOTES:

Objective of pilot project is to provide counterpart organizations with guidance for the choice and utilization of indicators for sustainable land management

The paper discusses indicators and their use. It makes the following points:

Sustainable land management is a prerequisite to sustainable agriculture and agriculture development. It is a key element of Agenda 21's goal of sustainable development (Chapter 14).

Different indicators are needed for different levels of decisionmakers.

Quantitative indicators are preferred, but reliable quantitative data is rare in most developing countries.

Takes FESLM's five pillars and adds:

Resilience enhance the potential to resist or buffer degradation

Equityassure equal access to land resources for all social groups.

Requirements for indicators on local and district, or project, level for use by rural development projects:

Indicators are specific to the social and ecological environment of farmers/pastoralists.

Indicators are identified through a participative process.

Indicators reflect broad local, indigenous knowledge.

Indicators need to be understandable for land users (such as enlargement of erosion rills, vegetative cover of pastures).

Monitoring and data collection should allow the participation of farmers/pastoralists.

Indicators should fit the specific problem to be overcome and the needs of the users of the information.

Indicators need to be sensitive to short-term changes in the system.

It must be possible to repeat the observations over certain periods of time.

The choice of indicators needs to take the availability of personnel and laboratory capacities into account.

Costs of surveying, processing, and evaluation need to be in sound relation to the costs of project implementation.

Existing databases should be enlarged.

Monitoring and evaluation needs to be organized to allow its continuation by the counterpart organization, even after expiration of the project.

Storage of and access to data over a prolonged period needs to be assured.

KEY WORDS: Indicators (general), Framework for the Evaluation of Sustainable Land Management (FESLM), productivity, security, protection, resilience, viability, acceptability, equity

GTZ. 1997. *Indicators of Sustainable Land Management: A Literature Review.* Deutsche Gesellschaft fur Technische Zusammenarbeit GmbH, Eschborn, Germany. 95 pp.

NOTES:

The object of the literature review was to provide an overview of the international discussions on indicators and to search for relatively simple and cost-effective monitoring methods. These methods can be based on "scientific," exogenous, or local (indigenous) knowledge. The use of indigenous knowledge has the great advantage of allowing participation by the target group in the monitoring process. Little could be found in the available literature on "simple" monitoring methods or participative monitoring and evaluation.

For a broad long-term adoption of new land management practices, economic viability is a prerequisite. No farmer will invest his labor and capital in the protection of land resources without a significant economic benefit. Special attention was given to socioeconomic aspects in the literature study; however, no specific information could be found.

The literature review gives an overview of the actual discussion on indicators and reveals also the weak issues, such as lack of simple, cost-effective monitoring methods and socioeconomic indicators. The challenge to development organizations, therefore, is to spend more effort in the development of impact indicators and adequate monitoring methods in order to assure the high quality of development projects.

KEY WORDS: Indicators (general), acceptability, indigenous knowledge, land quality, productivity, protection, security, viability

Hambly, H. and Angura, T.O. 1996. *Grassroots Indicators for Desertification: Experience and Perspectives from Eastern and Southern Africa.* International Development Research Centre, Ottawa, ON. 168 pp.

NOTES:

Argues that conventional methods and standards associated with the planning, monitoring, and evaluation of research and development projects have tended to be dominated by Euro-American scientific perceptions of environmental and development change using "top-down" approaches to data collection and analysis. The overall objective of this book, as well as the project supported by the International Development Research Centre, which led to the drafting of these papers, is to draw attention to the subject of "grassroots indicators:" measures or signals of environmental quality or change formulated by individuals, households, and communities, and derived from their local systems of observation, practice, and indigenous knowledge. For example, the fertility of soil in a specific area based on the types of trees growing there. The "environment" is defined here in its widest sense to cross economic, social, cultural, and ecological boundaries, and therefore seeks to open up the rigid sectoral approach typically used to delineate environment and development indicators.

KEY WORDS: Indigenous knowledge

Hammond, A. Adriaanse, A. Rodenburg, E. Bryant, D. and Woodward, R. 1995. "Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development." World Resources Institute, Washington, D.C. 43pp.

NOTES:

This work extends the World Resources Institute's previous work on indicators. It spells out an approach that structures environmental pressure indicators into four highly aggregated indices: pollution/emission, resource depletion, biodiversity and human impact. The working assumption is that a similar approach could be taken to construct state and response environmental indicators.

KEY WORDS: Indicators (general)

Hanson, R.G. and Cassman, K.G. 1994. "Soil Management and Sustainable Agriculture in the Developing World," pp 1733 in *15th World Congress of Soil Science,* Acapulco, Mexico, 1016 July 1994. Volume 7A: Commission VI Symposia. Sociedad Mexicana de la Ciencia del Suelo, Mexico.

ABSTRACT: World population is projected to increase from 5.4 billion in 1990 to 8.5 billion by the year 2025. The developing world is expected to account for 84 percent of this population growth. It is only recently that policymakers have accepted that the 6070 percent needed increase in food production, plus demands for fibre, fuel, and construction materials, must come from already exploited soil resources of which 88 percent possess one or more constraints to sustainable production. These population increases will place higher pressures on arable land resources from the present 3.57 persons ha-1. In Asia this is already at 11.1 persons ha-1. It has only recently been accepted in policy groups that improved soil productivity for sustainable production is the foundation upon which these new demands must be met.

Results from the Global Assessment of Soil Degradation (GLASOD) study report that humaninduced degradation of our vegetated soils has increased from 6 percent in 1945 to 17 percent in

1990, and with our present stewardship policies could increase to 25 percent by 2025. All 11 taxonomic units and over 5.0 M series have been identified within the developing world. The dominant orders are: 23 percent Oxisols (oxic horizon), 20 percent Ultisols (<35 percent base saturation), 16 percent Entisols (recent soils), 15 percent Alfisols (>35 percent base saturation), and 14 percent Inceptisols (young soils). Major management constraints include: 41 percent physical constraints, 27 percent low nutrient reserves, 23 percent aluminium toxicity (another 16 percent are acidic), 15 percent high P fixation, 26 percent low K reserves, and 9 percent have low CEC. Over 60 percent have variable charge, and 30 percent have mixed charges requiring special nutrient management.

Soil management research in this domain has been highly focused on: soil characterization and inventories needed to guide research and planning; physical properties and water dynamics; managing the chemical deficiencies and imbalances; and soil biology. The results of these research policies have been to exploit the soil resources to achieve some degree of self-sufficiency in production of basic food requirements and to supply unprocessed commodities for export to earn hard currencies for industrial development. Such policies only offer short-term gains that result in long-term degradation of the soil resource base and often permanent destruction of the environment.

Briefly reviewed in this paper are examples of soil management research that offer:

1. Options for sustainable agriculture production technologies that could reduce deforestation in the humid tropics

2. Management components that offer risk reduction and sustainability for some semiarid domains

3. Analysis with sustainability indicators (partial and total factor productivity analysis) of past successes and second generation challenges now facing rice farmers in the intensively managed systems in Asia.

These examples support the need for: improved capacity-based inventories for our soil resources; integrating production component research into conservation management systems; sustainability indicators to monitor the impact of exploitation on the quality of soil resources; and public policies focused on sustainability of soil resources as well as the institutional capacities to respond to changing demands and policy implementations.

KEY WORDS: Indicators (general), sustainable land management

Hart, R. 1994. "Summary, Conclusions, and Lessons Learned from the SANREM/INFORUM Electronic Conference on Indicators of Sustainability." Internet, January 15-April 22, 1994 INFORUM, World Wide Web http://tdg.uoguelph.ca/www/FSR/collections/indicator.html

NOTES:

Moderated discussion organized around series of questions that might typically be addressed by an interdisciplinary group working together to develop and use indicators of sustainability as part of a process to find more sustainable land use systems.

Conclusions:

1. There are many different multilateral, bilateral, and national public and private institutions interested in indicators of sustainability.

2. Because of different definitions of sustainability and interest in sustaining different systems, there are different approaches to the concept of indicators of sustainability.

3. The current state of the art of the methodology needed to be able to develop and use indicators of sustainability is, in general, not well-developed, but ideas on how to identify possible indicators are emerging.

It is important to agree early in the indicator development process how the indicator(s) will be used (qualitative signals, quantitative predictors, in multifactor analyses) before developing a set of possible indicators.

1. Intuitive, more subjective, approach: Allows people to integrate past experiences, which are impossible to capture quantitatively

2. Selection from a menu based on past experience approach: Past experience with measuring system performance and sustainability indicators allows us to make a list of likely candidate indicators for a given site.

3. Cause/effect or analytical approach: Analyzing how production methods affect productivity capacity.

KEY WORDS: Indicators (general)

Hawtin, G.C. 1994. "Agricultural Biodiversity and Ecosystem Health," pp. 4950 in Nielsen, N.O., ed. *Proceedings of an International Workshop: Agroecosystem Health*, Ottawa, ON, 19 June 1994. University of Guelph, Guelph, ON. 114 pp.

NOTES:

Pillar: Protection
Indicator: Diversity
Comments: In using diversity estimates as indicators of ecosystem health, it is probably of little use to try to establish target levels and acceptable ranges. In monitoring diversity, however, we should note directions of change. If diversity is decreasing we should be alerted to a possible decline in ecosystem health and should look hard at the underlying causes.

KEY WORDS: Protection, biodiversity

Henninger, N. 1992. "Environmental Impact and Sustainability Indicators for K2." World Resources Institute, Washington, D.C. 58 pp.

NOTES:

K2 is the envisaged successor of CAPPA (Computerized System for Agricultural and Population Planning Assistance), a computerized training tool for agricultural planning and policy analysis developed by the FAO.

The purpose of K2 is to provide a set of techniques for analysis and projections, plus an adaptable database for agricultural policy analysis and planning. Whereas CAPPA was designed primarily as a training tool, K2 will be an operational tool for policy analysis and planning. In their planning exercises K2 users should be able to perceive impacts arising from different agricultural policies on production, labor, investment, foreign exchange, land resources, and the environment. While K2 users will test different hypotheses, the training session will demonstrate the interconnectedness of population, economy, agriculture, and the environment.

KEY WORDS: Expert system

Hillary, N. Spearin, M. and Culver D. 1995. "Farm Resource Management Indicator: Inputs Management Component." Report 8. Policy Branch. Agriculture and Agri-Food Canada. Ottawa. ON. 23 pp.

NOTES:

This paper describes the approach proposed for collecting information on inputs management practices. It discusses the rationale for asking various questions related to best management practices (BMPs); the testing of those questions prior to the survey; issues related to the selection of universe (both coverage and type of farm to be surveyed); desired levels of geographic reporting, which will affect sample size and selection as well as costs; the utility of using the proposed computer-assisted telephone interviewing (CATI) approach for data collection; and roles and responsibilities for various aspects of the project.

How inputs are used and managed relates to environmentally sustainable agriculture in several ways. Improper use and application of inputs such as pesticides and nutrients can adversely affect on-farm resources, such as soil, and off-farm resources, such as water quality and biodiversity. Through sound management and use of BMPs inputs can be used in a manner posing little or no risk to the environment while contributing to productivity, a safe food supply, and farm financial health. It is therefore appropriate to include inputs management factors within the larger suite of agri-environmental indicators being developed.

KEY WORDS: Acceptability, inputs

Hobbs, P. and Morris, M. 1996. "Meeting South Asia's Future Food Requirements from Rice-Wheat Cropping Systems: Priority Issues Facing Researchers in the Post-Green Revolution Era." NRG Paper 96-01. CIMMYT, Mexico. 46 pp.

ABSTRACT: The importance of rice-wheat cropping systems in meeting present and future food needs in South Asia is reviewed. Evidence from a number of factor productivity studies, which analyze yield trends after adjusting for changes in levels of input use, suggest that growth in the productivity of South Asia's rice-wheat cropping system is leveling off and, in some areas, declining. Some probable causes of this disturbing trend are considered in the report, including soil-related factors (depletion of soil chemicals, soil physical problems from puddling soils for rice or repeated cultivation for wheat); problems relating to the quantity and quality of irrigation water; continuous and intensive cereal cultivation, which has increased the incidence of pests (including weeds) and diseases; and delaying planting of wheat following rice, a common practice in many rice-wheat systems, which severely reduces wheat yields. Changes in the organization and management of research that are required to restore growth in productivity are discussed in the final sections of the paper.

NOTES:

Pillar: Productivity
Indicator: Productivity trend
Scope: Local, regional, national
Unit of measurement: Tons/ha, compared over time
Threshold: Productivity growth in South Asia is slowing, suggesting that the easy gains from the original Green Revolution technologies for the most part have been realized. Throughout large parts of South Asia's rice-wheat beltparticularly the irrigated partsadoption of modern varieties of crops is now virtually complete, fertilizer rates are approaching optimal levels, and the potential for affordable irrigation is largely exhausted. By implication, if growth in food production is to keep pace with projected increases in demand, new sources of productivity growth will have to be tapped.

Pillar: Viability
Indicator: Input use

Scope: Local, regional, national
Unit of measurement: Kg/ha

Pillar: Acceptability
Indicator: Crop variety
Brief description: Rice and wheat yields in South Asia increased noticeably following the introduction of modern varieties. Wheat yields in South Asia have followed a growth pattern similar to that of rice yields, increasing sharply following the introduction of modern varieties and rising steadily ever since. From 1966 to 1990 average wheat yields for the region as a whole more than doubled, rising from just over 1.0 t/ha to about 2.3 t/ha.
Scope: Local, regional, national
Unit of measurement: Tons/ha of variety, compared over time

Conclusion: Thirty years after the onset of the original Green Revolution in South Asia, it is becoming increasingly clear that the engine of growth is running out of steam. Modern varieties, fertilizer, and irrigation offer increasingly limited prospects for raising yields in the future, especially in areas where adoption of these inputs is already extensive. Evidence for this conclusion comes from a number of intensively cultivated districts in northwestern India and northeastern Pakistan, where growth in rice and wheat yields has slowed noticeably during the past two decades, even though farmers have replaced older varieties of crops with newer ones and tripled fertilizer doses. Although modern varieties, fertilizer, and irrigation do have the potential to deliver productivity gains in areas where their use is still suboptimal (for example, eastern India, much of Bangladesh, and Nepal) in the heart of the South Asian grain belt where rice-wheat cropping systems are most productive, these traditional sources of productivity growth are largely exhausted.

KEY WORDS: Productivity, viability, acceptability, inputs, crop variety

Ingham, E. 1996. "The Soil Foodweb: Its Importance to Ecosystem Health." An Organic Growers' Home Page. World Wide Web http://www.rain.org/ ~sals/ingham.html

NOTES:

Pillar: Protection
Indicator: Soil foodweb
Description: The numbers, biomass, activity, and community structure of the organisms that comprise the soil foodweb can be used as indicators of ecosystem health because these organisms perform critical process and functions.
Scope: Local
Unit of measurement: Ratio of fungal to bacterial biomass
Thresholds: Total fungal to total bacterial biomass ratio less than 1 (F/B<1). The most productive agricultural systems have a 1:1 ratio. When agricultural soils become fungal-dominated, productivity will be reduced.

Conifer forest soils are fungal dominated and the ratio in which seedling regeneration occurs is above 10. In general, productive forest soils have ratios greater than 100.

KEY WORDS: Protection, soil quality

Kobrich, C. and Rehman, T. 1996. "Sustainability and the MCDM Paradigm: Model Construction and Optimization."*VIII Congress of the European Association of Agricultural Economics*. Edinburgh, September 1996.

ABSTRACT: An analytical framework is presented that is capable of assessing the impact of development tools on the sustainability of peasant farming systems (FSs) in any microregion of a country. Any approach to the analysis of sustainability should begin with a clear definition of sustainability, which considers economic, environmental, and social aspects. The methodology presented here considers first, the identification of relevant FSs; second, the construction of farm models;third, aggregation into a microregional model; and finally, the optimization of this model using the multi-criteria decisionmaking (MCDM) paradigm. This framework is developed in the context of peasant farmers of Chile's VI Region, and results relating the first two stages are reported. It is concluded that the multivariate analysis and sequential semistructured surveys are suitable tools to support the construction of MCDM models for the evaluation of sustainability in its widest significance.

KEY WORDS: Sustainability, indicators (general), viability

Kuik, O. and Verbruggen, H., eds. 1992. *In Search of Indicators of Sustainable Development.* Kluwer Academic Publishers, The Netherlands.

NOTES:

Finding measuring rods to answer questions such as whether a region or country's economic performance was more sustainable in 1991 than in 1981 was the objective of workshops organized in 1989 and 1990 by the Institute for Environmental Studies of the Free University of Amsterdam at the request of the Netherlands' National Institute of Public Health and Environmental Protection. The papers presented at these workshops, which were attended by both scientists and policymakers, form the core of this publication.

The search for indicators of sustainable development means a search for policy-relevant and coherent information that adheres to the following criteria:

Information that gives a clear indication of whether objectives will be met

Information on the system as a whole

Information of a quantitative character

Information understandable for nonscientists

Information containing parameters that can be used for longer periods.

KEY WORDS: Indicators (general)

Lal, R. 1994. "Methods and Guidelines for Assessing Sustainable Use of Soil and Water Resources in the Tropics." Soil Management Support Services Technical Monograph 21. U.S. Agency for International Development, Washington, D.C. 78 pp.

SUMMARY: Degradation of soil and water resources and environmental pollution are perceived to be major problems in the tropics. Vast areas of land are claimed to be degraded, some of them irreversibly, by a wide range of degradative processes, such as: accelerated erosion and desertification, compaction and hard setting, acidification, decline in soil organic matter content and biodiversity, and depletion in soil fertility. The land area degraded by different processes in the tropics is estimated to be 915 × 106 ha by water erosion, 474 × 106 ha by wind erosion, 50 × 106 ha by physical degradation, and 213 × 106 ha by chemical degradation.

Soil and environmental degradation, low productivity, and resource-based low-input agriculture go hand-in-hand. Soil and environmental degradation are perpetuated by land misuse and exploitive and fertility-mining systems of subsistence agriculture. Resource-poor farmers of the tropics are trapped in the ever-tightening grip of a soil degradation-low productivity-poverty-low input-more degradation cycle.

The concept of sustainability, useful and relevant as it is, needs to be made quantitative, objective, and reliable. There is a need to develop criteria and methods of quantitative assessment of sustainable use of soil and water resources. To do this is to: (a) identify soil and water indicators of sustainability; (b) establish quantitative relationships between soil and water indicators and soil modifying degradative processes on the one hand and productivity on the other; (c) define critical limits of soil and water indicators in relation to threshold values beyond which productivity decline is severe and rapid, and beyond which soil and water resources are degraded to the point of no return; (d) establish indices of soil sustainability and soil quality; and, (e) develop standardized methods for assessment of soil and water indicators.

Degradation of soil and water quality and sustainability of resource use must be expressed in terms of their impact on productivity and environmental quality. Productivity is related to land use and management systems. Agronomic productivity should be assessed in relation to key indicators, such as topsoil depth, texture, structure, available water and nutrient capacity, pH, soil organic carbon content, cation exchange capacity, and toxic levels of some elements. Productivity loss is permanent and irreversible only if it cannot be restored by alternate land use and science-based inputs.

There is a sequence of steps and checklists that needs to be followed while assessing use of soil and water resources. The first step is to define objectives of assessing sustainability. The next step is to conduct a detailed resource survey to evaluate the potential of and constraints on the resource base and identify predominant soil degradative processes. Evaluation of changes in soil indicators and productivity due to soil modifying processes is the next step. If productivity decline or change in soil indicator is drastic and severe, the next step is to change the land-use and management system and follow the iterative process.

The science of quantification of sustainability, development of indices of soil quality, and productivity is new and at formative stages of development. Consequently there are numerous researchable topics of high priority that require interdisciplinary, multi-institutional, and long-term ecological experiments established on benchmark soils in principal ecoregions of the tropics. Research is needed in several relevant issues including: (a) development and standardization of analytic procedures for *in situ* assessment of soil physical and hydrological indicators; (b) identification of techniques for establishment of the cause-effect relationship between soil indicators and degradative processes on the one hand, and productivity on the other; (c) development of indices of sustainability, soil resilience, and soil quality with relevance to the impact on production and environment; and, (d) development of appropriate predictive models.

It is equally important to involve farmers and practitioners in the process of research and development on issues of sustainable use of soil and water resources. Innovative farmers can be a valuable source of information and an interested partner with vested interests. Farmer participation can be useful in selecting: (a) practical indicators of relevant degradative processes affecting soil and water resources and economic productivity; and, (b) remedial or alternate land use, cropping systems, and inputs for reversing degradative trends. Application of the methodology and guidelines suggested in this report can help improve the database and provide reliable and objective assessment of the extent and severity of soil degradation in relation to its input on productivity, sustainability, and environmental quality.

NOTES:

Indicators of agronomic productivity

Indicator	*Scale and objectives of measurement*
Total biomass	Expressed per unit area, per unit time or both
Agronomic yield	Calculated per unit area, per unit time or both
Economic yield	Determined in terms of net returns

(table continued on next page)

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Resource use efficiency	Computed in terms of water, nutrient, or energy use efficiency
Potential vs. actual productivity	Potential productivity depends on inherent characteristics, inputs, and management
Land equivalent ratio	Expressed as a measure of the intensity of land use
Cropping intensity	Computed as numbers of crops grown per year on the same piece of land
Area time equivalent ratio	Considers growth duration of each crop in a mixed cropping system
Energy flux	Total energy (caloric value) produced
Thermodynamics	Energy produced per unit of energy input

Indicators of soil and water sustainability for the humid tropics

Processes/parameters	*Indicators*
Soil	
Acidification	pH, total acidity, base saturation, exchangeable Al and Mn.
Soil fertility	Total and plant available N, P, K, Ca, Zn, S, soil organic matter content, and activity and species diversity of earthworms and termites.
Soil structure	Aggregation, mean weight diameter, bulk density and strength, porosity, and pore size distribution, erodibility, rooting depth
Soil water	Available water capacity, infiltration rate, saturated and unsaturated hydraulic conductivity
Soil erosion	Potential risks and actual erosion rate under different management systems, soil loss tolerance, erosion, and crop productivity
Water	
Water balance	Runoff rate and amount, interflow, soil water storage, water deficit
Water quality	Dissolved and suspended loads, type and concentration of agricultural chemicals, eutrophication
Climate	
Rainfall	Intensity and amount, rainfall distribution erosivity, return period
Energy budget	Net solar radiation, and soil and air temperatures, energy budget

Indicators of soil and water sustainability for semihumid and semiarid tropics

Processes/parameters	*Indicators*
Soil	
Compaction and hardsetting	Crust strength, bulk density, penetration resistance, porosity and pore size distribution, infiltration rate, cracking patterns, and intensity
Soil erosion	Magnitude of wind and water erosion and rate of gully advance, soil erodibility, erosion-productivity relationship, soil loss tolerance
Soil structure	Aggregation and aggregate stability, pore size distribution
Drought stress	Available water capacity, rooting depth, water deficit, probability of drought during the season
Soil fertility	Soil organic carbon, total and plant available macro-and micro-nutrients
Soil fauna	Activity and species diversity of termites
Salinization	Electrical conductivity, SAR, total soluble salts
Particle size distribution	Stoniness, texture
Water	
Water balance	Water deficit, water balance on weekly basis
Quality	Concentration and nature of soluble salts in surface and ground waters, sediment load, eutrophication
Climate	
Rainfall	Onset and cessation of rains, growing season
Energy budget	Soil and air temperatures, evaporative demand
Wind	Wind velocity and directions, sand blasting

Soil and water indicators for the arid tropics and irrigated agriculture

Processes/parameters	*Indicators*
Soil	
Drought	Water balance, growin season, surface, and ground water resources, water quality, soil and air temperatures
Salinity	Salt concentration in the root zone, nature of salts and SAR, drainage and leaching of salts, plant indicators for salinity
Erosion	Wind erosion, texture and structure, compaction, sand dune movement and stabilization, sand blasting of seedlings
Soil fertility	pH, total and plant available nutrients, rooting depth
Surface stoniness	Size and concentration of stones and concretions
Irrigation	
Type and availability	Design efficiency, crop water requirement, scheduling irrigation
Drainage	Profile drainage, surface drainage features, drainage outlet, waterlogging, recycling of drainage water
Water table	Level and fluctuations in water table, and aquifer recharge
Climate	
Aridity	Evaporative demand, soil and air temperatures, relative humidity
Wind	Wind velocity and duration

KEY WORDS: Productivity, viability, yield performance, resource management, inputs, soil management, soil quality, water quality, rainfall, security, protection, indigenous knowledge

Lammerts van Bueren, E.M. and Blom, E.M. 1997. *Hierarchical Framework for the Formulation of Sustainable Forest Management Standards.* The Tropenbos Foundation. Bachhuys Pub., The Netherlands. 82 pp.

SUMMARY: The publication describes principles, criteria, and indicators for sustainable forest management (SFM). Collectively, these are tools for monitoring and reporting or to serve as reference points for assessment of current forest management. The concern at the international level is for monitoring and reporting, but there are also market opportunities for forest products coming from sustainable, or at least well-managed, forests. There are many international, national, and private-sector organizations developing standards for SFM; this report is an effort to bring them all together.

The hierarchy proposed by the Tropenbos framework includes the following typology of parameters:

Input: An object, capacity, or intent operated on by any human driving force (for example, a forest management plan)

Process: The management process or human activity precipitated by the input

Outcome: The result(s) of the action.

The hierarchy solves the problem of how to cope with the many and varied procedures currently available to assess forest management.

The hierarchy attempts first of all to use available data as much as possible. In the initial stages thresholds and targets should be set conservatively and adjusted as new data and information become available. A pure mathematical approach to criteria and indicators will not be practical, and assessment of the quality of forest ecosystems will have to rely on professional judgment to some degree. In practice, the assessment of the quality of forest management boils down to a check on compliance with indicators and norms, not principles and criteria. However, without the formulation of principles and criteria and an understanding of the indicators that link them, this check is not meaningful.

The publication reviews existing standards from the following sources:

International Tropical Timber Organization (1992)

Amazon Cooperative Treaty A.C. (1995)

Ministerial Conference on the Protection of Forests in Europe, Helsinki (1994)

The Montreal Process (1995)

African Timber Organization (1996)

Deskundigengroep Duurzaam Bosbeheer (Working Group of Experts of Sustainable Forest Management) (1994)

Forest Stewardship Council (1996)

Scientific Certification Systems (1995)

Smartwood Programme (1993)

The Soil Association Marketing Company Ltd.Responsible Forestry Programme (1994)

CIFOR (1996).

NOTES:

Pillars: Productivity, protection, viability, acceptance
Indicators: Varied, related to assessing forest quality
Scope: National, global
Unit of measurement: Varied

KEY WORDS: Forestry, principles, criteria, indicators, hierarchy

Larson, W.E. and Pierce, F.J. 1994. "The Dynamics of Soil Quality as a Measure of Sustainable Management." *In Defining Soil Quality for a Sustainable Environment,* SSSA-Special Publication 35. Soil Science Society of America, Madison, Wis.

NOTES:

Pillar: Protection
Indicator: Soil quality
Description: The capacity of a soil to function, both within its ecosystem boundaries and with the environment external to that system
Scope: Local
Unit of measurement: Expressed as a function of attributes
Method of Measurement: The dynamics of soil quality can be identified by expressing soil quality, Q, as a function of measurable soil attributes, qi values; measuring the variation of these attributes over time; and evaluating the dynamics of soil quality, dQ/dt, using models or statistical quality control procedures.

$$\frac{dQ}{dt} = f\left[\frac{\frac{(q_{it} - q_{it0}}{q_{it0}} \cdots \frac{(q_{nt} - q_{nt0}}{q_{nt0}}}{dt}\right]$$

Among the soil attributes identified:
- Nutrient availability for the region
- Total organic C
- Labile organic C
- Texture
- Plant-available water capacity
- Structure
- Strength (bulk density or penetration resistance)

Maximum root depth
pH
Electrical conductivity.

KEY WORDS: Protection, soil quality

Lawas, C.M. and Lining, H.A. 1996. "Farmers' Knowledge and GIS." Center for International Research and Advisory Networks, Enschede, The Netherlands. World Wide Web http://www.nufficcs.nl/ciran/ikdm/4-1/articles/lawas.html

ABSTRACT: Indigenous knowledge has become a valuable input in planning and decisionmaking related to sustainable management of natural resources. This article presents a method of collecting genuine information from indigenous farmers and using a computer system to store important spatial and geographic information. The retrieval and quantification of such indigenous information by means of a GIS maximizes the usefulness of the data. The GIS also makes it possible to create, analyze, and process scenarios using the information stored in the computer. Moreover, it approaches the rationality and validity of the farmers' knowledge by relating their conception of elevation to the intensity of their cropping practices.

KEY WORDS: Indigenous knowledge

Lefroy, E.C. and Hobbs, R.J. 1992. "Ecological Indicators for Sustainable Agriculture." *Australian Journal of Soil and Water Conservation* 5:4, 22-8.

ABSTRACT: Achieving sustainability in agriculture involves simultaneously satisfying ecological, economic, and social requirements. It is possible to define the required economic and social conditions relatively easily in terms of the viability of individual farm businesses and the regional economy and support to rural populations. The ecological conditions that need to be met are more difficult to define, and this remains a major obstacle to the development of sustainable agricultural systems. This paper puts forward a framework that may be useful in deriving indicators of ecological sustainability. It is suggested that indicators should aim to reflect the condition of the four fundamental characteristics of natural systems, namely the cycling of water and nutrients, the flow of energy, and the role of species richness in the dynamics of the biotic component. As an example a preliminary and very simple set of indicators derived for the wheatbelt of Western Australia is given.

NOTES:

Authors conclude that subjecting agriculture to simple ecological analysis can help to highlight deficiencies in existing systems of land use and suggest possible solutions. Ecological indicators that attempt to reflect the integrity of fundamental processes may prove useful in focusing the design of ecologically sustainable agricultural systems. Clearly more work is required to determine useful indicators and establish present and desired values for the few indicators suggested here.

Pillars: Security, protection, viability, acceptability
Scope: Local
Location: Western Australian wheatbelt

Indicator	*Description*	*Measure*	*Level*		
			Present	Transitional	Desirable
WATER CYCLE					
1. Water use potential	Perennial plant density	tree/ha	<1	10	3040
	Annual plant density by season	%cover			
2. Ground water quality	Conductivity	mS/m	3450		<0800
	Total phosphorus	mg/L			0.050.15
	Total nitrogen	mg/L			1.01.4
	Total solids	mg/L			
3. Surface water quality	Conductivity	mS/m			0400
	Total phosphorus	mg/L			
	Total nitrogen	mg/L			
	Suspended solids	mg/L			
4. Ground water accession	Change in depth to water table	m			
NUTRIENT CYCLE					
1. Nutrient loss through wind & water erosion	Retention of surface cover	% stable vegetation cover	>×200	×25	×10
	Average distance between permanent shelterbelts	units of shelterbelt height			
2. Leaching of applied nutrients	Coincidence between soil types and management units	%			100
3 Soil biological activity	Population density of key species	number/cm3			
	Level of metabolic activity in soil	respiration rate			
	Rate of OM and surface litter breakdown	kg/ha/yr			
	Acidity/alkalinity	pH change/yr			
4 Nitrogen fixation	Density of plant species with N-fixing associations	% cover			
ENERGY					
1. Energy inputs in breakdown	Calorie equivalent herbicide per calorie grain	ratio			
	Calorie equivalent fertiliser per calorie grain	ratio			
	Calorie equivalent liquid fuel per calorie grain	ratio			
2. Solar energy interception	Weighted average sowing date for crops	ratio			
	Weighted average maturity date for crops	ratio			

(table continues on the following page)

(continued)

Indicator	*Description*	*Measure*	*Level*		
			Present	*Transitional*	*Desirable*
	Annual pasture density	% ground cover			
	May		020	10	15
	July		130	15	30
	September		560	40	60
DIVERSITY					
1. Diversity of plant species and forms	Species count by plant form: trees, shrubs, perennial herbs, perennial grasses, annual grasses; annual herbs	Proportion of species originally present			
2. Representation of plant functional groups	Proportion of areas occupied by:	%			
	Trees		3	5	1020
	Shrubs				
	Perennial herbs		2	10	20
	Annual pasture		45	40	30
	Crops		45	45	40
3. Diversity of native fauna	Key species count: birds; mammals; other	Proportion of species originally present			
4. Soil biological activity (see above)					
5. Conservation status	Congruence between protected remnants and minimum subset		20	50	100
6. Connectivity	Percentage of remnants connected by corridors				

KEY WORDS: Security, protection, viability, acceptability, water quality, soil quality, inputs, biodiversity

Lightfoot, C. Prein, M. and Ofori, J.K. 1996. "The Potential Impact of Integrated Agriculture-Aquaculture Systems on Sustainable Farming," pp. 51-6 in Prein, M. Ofori, J.K. and Lightfoot, C., eds. *Research for the Future Development of Aquaculture in Ghana.* International Centre for Living Aquatic Resources Management, Philippines. 94 pp.

ABSTRACT: Farmer participatory experiments on integrated agriculture-aquaculture (IAA) on smallholder farms in Ghana were conducted. Based on preliminary results, the potential of this integration technology for making existing, traditional farming systems more sustainable clearly exists. Household economics, together with four sustainability indicators, show that farms that adopt IAA become more sustainable. Additional environmental benefits, as well as increased awareness among farmers as to the effects of their activities, can be achieved. Possible measures for policy formulation towards widespread adoption are suggested.

NOTES:

For the comparison of IAA with existing nonintegrated systems, the researchers used species diversity, bioresource recycling, natural resource systems capacity, and economic efficiency as indicators for sustainability.

Pillar: Productivity
Indicator: Diversity
Unit of measurement: Diversity is the number of species cultivated
Comment: A weakness is that it does not take into account the extent of the cultivation. The authors speculate that diversity contributes to sustainability through biocontrol of pests, reduced risks through compensation by one species for reduced production in another, and maintenance of a larger range of germplasm.

Pillar: Viability
Indicator: Recycling
Unit of measurement: Recycling is the number of bioresource flows. For example: maize stover to goats and sheep, pond mud on vegetables, vegetable waste to feed fish, and so forth
Comment: A weakness is that the indicator does not take into account the volume of flows. The authors speculate that recycling contributes to sustainability through reduced pollution, utilized wastes, and more N and P in more available forms.

Pillar: Viability
Indicator: Capacity
Unit of measurement: The capacity of the natural resource systems is the total output from each system, including internal and external flows, expressed in monetary terms, divided by the number of resource systems.
Comment: A weakness is that the indicator does not take account of the external inputs to detect resource mining. The authors speculate that capacity contributes to sustainability through greater offtake and reduced offsite effects.

Pillar: Viability
Indicator: Economic efficiency
Unit of measurement: Economic efficiency is profit or net income, which is gross return minus total costs.
Comment: A weakness is that the indicator does not take account of the arbitrary nature of assigning opportunity costs for inputs, especially bioresources.

KEY WORDS: Productivity, viability

Lightfoot, C. Dalsgaard, J.P. Bimbao, M.A. and Fermin, F. 1993. "Farmer Participatory Procedures for Managing and Monitoring Sustainable Farming Systems." *Journal of the Asian Farming System Association* 2: 6787.

ABSTRACT: Development imperatives are changing. Maximizing commodity productivity is giving way to sustainable management of natural resources. High external input farming is giving way to low external input farming. With these changes come the needs to help farmers manage the integration of livestock, forestry, and aquaculture into crop-based farms and to assess the impact of these systems on the environment. Our objective is to devise a farmer-participatory method that not only improves farmer management of natural resources, but also monitors the impact of improvements. Farmer-participatory methods first identify indigenous categories of natural resources. For each natural resource type an inventory of crop, vegetable, tree, livestock, and fish enterprise is collated. This information is elicited through drawing maps and topographical transects of the resource systems. Bioresource flows between enterprises and resource types are then modeled in farmers' conceptual diagrams. Farmers monitor and manage resource flows

by recording inputs directly onto their conceptual models. At the start and end of a season the farmers bring their quantified models to a group meeting where lessons are learned "farmer-to-farmer," and researchers collect the data recorded and introduce new techniques to manage natural resources. A rolling design of farmers' experiments in natural resource management is put into place.

Case studies over two seasons with three farmers in the Philippines illustrate how natural resource management can improve. The impacts of these improvements in natural resources management are assessed in terms of changes in economic efficiency, biological material recycling, species diversity, and resource system capacity. Time series analyses of the four indicators show that dynamism and reversals characterize all farms. Rapid increases and decreases in all indicators occur. Results suggest that high performance in all indicators can occur simultaneously and that economic loss from crop failure does not jeopardize performance in species diversity and recycling. Although still in its early stages, participating farmers tell of improved resource management and express interest in long-term monitoring. However, time series data on more farms are needed to develop more and better indicators.

KEY WORDS: Indigenous knowledge, acceptability, resource management

Lyson, T.A. and Welsh, R. 1993. "The Production Function, Crop Diversity, and the Debate Between Conventional and Sustainable Agriculture." *Rural Sociology* 58:3, 424-39.

ABSTRACT: Organizational assumptions embedded in the production function of neoclassical economics have served to structure production agriculture in the United States for the past 100 years. The narrow focus of the production function on the inputs of land, labor, capital, and management and the use of on-farm profitability as the primary definition of sustainability have come under attack from sustainable agriculturalists who argue that social and environmental consequences of production are as important as economic outcomes. Using diversity of crops harvested as an indicator of sustainability, the production function is operationalized to inform the debate between the conventional, neoclassical model of production and the alternative, sustainable model. Censuses of agriculture data from 1978, 1982, and 1987 are used in both crosssectional and temporal models. Results show that increases in expenditures for equipment and machinery, prevalence of corporate farms, higher rates of tenancy, and the prevalence of large farms are associated with lower levels of diversity at the county level. Conversely, higher levels of diversity are found in counties with greater farm labor expenses, where there are more mediumsize farms and farmers are more likely to farm fulltime.

NOTES:

Pillar: Acceptability
Indicator: Diversity of crops harvested
Description: Authors assume that crop diversity is an indication of the adoption of sustainable practices; that is, favoring significantly reduced use of synthetic farm chemicals, smaller farm units, appropriate technology, reduced energy use, greater farm and regional self-sufficiency, minimally processed foodstuffs, conservation of finite resources, and more direct sales to consumers.
Crops: Wheat, corn, soybeans, orchards, alfalfa, rice, barley, oats, dry edible beans, Irish potatoes, snap beans, cotton, sorghum, other vegetables, cover crops, and other hay crops
Location: United States (2,919 counties)
Scope: Regional, national
Unit of measurement: Two different measures:

Simpson index the probability of an acre of harvested cropland being occupied by the most dominant crop
Coefficient of variation
Methods of measurement:
Simpson index based on the probability of choosing any two individuals at random from an infinitely large community [SI = SUM(n1 (n1-1)/N(N-1)), where ni = number of individuals in the acres of land and N = total number of crops]

Coefficient of variation the standard deviation of a sample population adjusted to be scale invariant. This is accomplished by dividing the standard deviation of a sample population by the mean. Its upper bound is reached when all available cropland harvested in a county is accounted for by one crop.

KEY WORDS: Acceptability, crop variety

MacDonald, K.B. and Gleig, D.B. 1996. "Indicator of Risk of Water Contamination from Nitrogen (IROWC-N)." Draft. Ontario Land Resource Unit, Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 41 pp.

ABSTRACT: One important component of the Environmental Indicators Project is an indicator that deals with the impact of agricultural activities on water quality. This indicator has been dealt with in terms of risk and is described as an Indicator of Risk of Water Contamination (IROWC). The agricultural activities that affect water quality include the kind of crops being grown and their rotation sequence, the inputs of nutrients and pesticides required to achieve yields that are economically sustainable, and general land management practices (such as subsurface drainage, buffer strips, tillage practices, and so on). These agricultural activities, which can be controlled by the land manager, also affect other indicators, in particular those dealing with soil quality/ degradation, greenhouse gas evolution, or sequestration and nutrient balance.

NOTES:

Pillar: Protection
Indicator: Risk of water contamination
Description: Identifies trends in the risk of water contamination from agrichemicals; the indicator will track primary agriculture's success in minimizing water pollution risks and identify areas at higher relative risk.
Scope: Regional, but can be used from national to field level
Unit of measurement: Ratio of the potential contaminant concentration (mg/L) to the maximum allowable concentration (mg/L). Indicator may be reported in risk classes.
Methods of measurement: IROWC utilizes a series of nested hierarchial levels, which range from national to field level, to provide a structure for analysis.

Risk is characterized by two general attributes: the possibility of an undesirable outcome (hazard) and the uncertainty of its occurrence, timing, or magnitude (exposure). IROWC is an indicator of risk to water quality from agricultural activities. The possibility of an undesirable outcome is determined by locating areas to which nutrients or pesticides are applied. The probability of exposure is determined related to a fixed threshold value chosen for IROWC (for N): the drinking water standard of 10 mg N03-N per liter. The potential magnitude is determined through a partial budget approach.

Inputs:
- Fertilizer N
- Manure N

Atmospheric deposition
N fixation by nonsymbiotic bacteria

Outputs:

Harvested crop
Denitrification
Leaching to ground water

Run off into surface water

The quantity of excess N in the soil is the difference between inputs and outputs.

Limitations: A variety of anthropogenic influences affect the overall nitrogen balance in the environment, but this project has considered only the impacts of agricultural activities. Nitrogen inputs from atmospheric deposition or nonsymbiotic nitrogen fixation are not included, nor are losses from denitrification. Other factors that affect rural land and water (such as nitrogen from rural septic systems) should be considered in placing this agricultural IROWC-N in perspective of the overall ecosystem health/integrity assessment for sustainable development.

Conclusions: IROWC-N is sensitive to the mix of crops and levels of nutrient inputs from fertilizer and manure. Additional work is required at a more detailed level to determine the effects of other management practices, such as conservation tillage.

A main feature of IROWC-N would appear to be the dynamics of nitrogen during the traditional noncrop period. Research on controlled drainage and with catch crops (crops grown late in the season to take up nitrogen and retain it in biomass over winter) offer some potential to mitigate the effects of intensive cropping on IROWC-N.

In addition to the direct requirements of the Environmental Indicators Project, the work on IROWC is also related to a variety of other studies dealing with water quality. Efforts are underway within the OECD countries to assess the impact of agriculture on water quality. The policy branch of Agriculture and Agri-Food Canada is interested in developing a predictive capacity that includes water impacts in order to evaluate various policy alternatives. Several INRA laboratories in France have research projects dealing with various aspects of agricultural impacts on water quality.

KEY WORDS: Protection, water quality, inputs

Mantel, S. and van Engelen, V.W.P. 1997. "The Impact of Land Degradation on Food Productivity: Case Studies in Uruguay, Argentina, and Kenya." Vol. I: Main Report. Report 97/01, International Soil Reference and Information Center, Wageningen, The Netherlands. 44 pp.

ABSTRACT: Land units may differ in their resistance to erosion and human-induced and climatic changes. Moreover, the impact of degradation on functional properties of land and its productive capacity may differ between land units and soils. The present study describes a mixed qualitative/quantitative methodology for assessment of the impact of erosion on productivity of a land use system, given the variability in natural conditions (for example, soils, landform, and climate). This approach is applied to three countries situated in two regionsSouth America (Uruguay and part of Argentina) and east Africa (Kenya)with different types of land use and in highly varying agroecological conditions. A chain of models was used to study the impact of erosion on crop production. The studies were based on national 1:1 M scale Soil and Terrain (SOTER) databases that were compiled for northern Argentina, Kenya, and Uruguay. Soils and terrain attributes are linked to a Geographical Information System (GIS), permitting spatial analysis. For stratification of climatic data the Agro-Ecological Zones (AEZ) maps of South America (in the case of Uruguay and Argentina) and Africa (for the case of Kenya) were used. Only the spatially

dominant soil component by AEZ was considered in the analysis. For these dominant soils of each mapping unit suitable for the land use, the potential yield before and after an erosion scenario of 20 years was calculated. The impact of change in soil properties, influencing crop performance, induced by removal of topsoil through sheet erosion is analyzed in this study. In the two countries in Latin America soil erosion affected mostly the physical properties of the soils, resulting in a calculated yield reduction of between 25 and 50 percent. In Kenya the largest yield reduction was mainly due to loss in soil fertility. Potential yields after erosion mostly ranged from 25 percent to more than 50 percent of the current situation. A complete set of maps of Uruguay and a selection of maps of Argentina and Kenya figure in this report, while the remaining maps of Argentina and Kenya, together with Pedo-Transfer Functions, are published in a separate volume.

NOTES:

Pillars: Productivity, protection
Indicators: Constraint-free yield
Water-limited yield
Nutrient-limited yield
Erosion
Scope: Regional, national
Unit of measurement: Qualitative, comparative

KEY WORDS: Degradation, productivity, erosion, AEZ, GIS, South America, Africa

Mathias, E. 1995. "Framework for Enhancing the Use of Indigenous Knowledge." Center for International Research and Advisory Networks, Enschede, The Netherlands. World Wide Web http://www.nufficcs.nl/ciran/ikdm/3-2/articles/mathias.html

ABSTRACT: With growing recognition of the value of indigenous knowledge for sustainable development, both the number of projects and the amount of information on indigenous knowledge have increased. Despite these efforts, however, development projects still appear to make little use of this valuable resource. Donors' recognition of indigenous knowledge often represents little more than lip service, seldom translating into action or funding. What more can be done by individual organizations working in the field of indigenous knowledge to promote its use for development?

The framework reviews past efforts and suggests future action. It highlights trends and illustrates them with a few examples. It has intentionally been kept short and precise, which means that many important publications and ongoing projects are not mentioned. The framework presented is based on two objectives, that are seen as essential in promoting the use of indigenous knowledge: (a) to increase and improve the available information on indigenous knowledge; and (b) to enhance the application of indigenous knowledge in development activities.

The framework is intended as an input for discussions rather than a final recommendation.

KEY WORDS: Indigenous knowledge

Mausbach, M.J. Unpublished. "Development of Soil Quality Indicators: Progress Report from the United States." Organisation for Economic Co-operation and Development, Paris. 10 pp.

NOTES:

Pillars: Protection, security, acceptability

Indicators:

Depth to root restricting layers
Soil compaction
Organic carbon
Potentially mineralizable carbon and nitrogen; basal respiration
Microbial biomass C&N

Aggregate stability
Texture
pH
Electrical conductivity
Cation exchange capacity, Al and bases
Surface crusts (mineral and biocrust)
Land cover/use
Site characteristics
Tillage
Erosion
Conservation/farming system

Scope: Local

Pilot study evaluating soil quality measurements and interpretive indices using the scientific, spatial, and historic framework of the National Resources Inventory sample database.

Interpretation of indicators at each site hinges on the development of reference values for indicators that represent a soil functioning at full potential. Ideally, reference values should be developed for each soil series and land use. However, this would be a monumental task. A more practical approach is to develop reference values for soils that function similarly.

Researchers will group soils that function similarly for land use such as row crops or closely grown crops such as wheat. Values of indicators from the study will be compared to the reference values to determine the state of the quality of soils in a region.

KEY WORDS: Protection, security, acceptability, soil quality, resource management

McCann, S. 1995. "Agricultural Indicators: Indicator Program Descriptions." World Resources Institute, Washington, D.C. World Wide Web http://tdg.uoguelph.ca/www/FSR/collection/ indicator/program.txt

NOTES:

This document includes profiles of 37 programs currently involved in developing indicators of agricultural sustainability. The profiles are arranged in four categories based on the focus of an organization's indicator output or reports. The categories include the global and national level; the regional level (ecoregion, watershed, landscape, and so on); the community, project, and farm level; and the soil level.

KEY WORDS: Indicators (general)

Melnychuk, N. Olfert, O. Youngs, B. and Gillot, C. 1996. "Monitoring Insect Populations in Saskatchewan Farming Systems," 22-3 in Stushnoff, C.T, ed. *Proceedings of the Second Sustainable Land Management Workshop*, University of Saskatchewan, 20 February 1996. Agriculture and AgriFood Canada, Saskatoon, SK, 29 pp.

NOTES:

Insects have always posed a threat to agricultural production. Mechanization and monoculture characteristics of modern conventional agriculture exacerbate this problem by simplifying the natural ecosystem. Simplification means a loss of natural checks and balances that results in recurrent cycles of pest outbreaks, often with devastating economic effect. These outbreak cycles have necessitated human intervention, often in the form of agrochemical inputs, to maintain the productive functioning of the agroecosystem. This need to replace biotic process with chemic technology has led to questions regarding the long-term sustainability of conventional farming practices.

The pest-natural enemy complex found in the crop is influenced by three factors under human control. The purpose of this study is to examine how these factors affect the insect fauna on Saskatchewan farms.

Management level and type of inputs. Fields from the high cereal input rotations had higher abundance of all three groups than the organic cereal rotation. The high input forage rotation had a greater abundance of herbivores; however predators and hymenoptera were higher in the organic forage rotation.

Surrounding environment presence of noncultivated areas near the field. More insects were found in the margins of the cereal rotation fields than in the crops. The forage rotation had a higher abundance of hymenoptera in the margin. Herbivore and predator numbers were higher in the crop. This is because of a large number of pea aphids found in the alfalfa fields.

Crop type. The type of crop being grown in a field influenced the abundance of insects collected. Alfalfa had the highest number and wheat had the lowest. Peas had an intermediate abundance.

Climatic condition will also influence the insect fauna.

KEY WORDS: Viability, acceptability, inputs, resource management, crop variety

Miller, F.P. and Wali, M.K. 1995. "Soils, Land Use, and Sustainable Agriculture: A Review." *Canadian Journal of Soil Science* 75: 4, 413-22.

ABSTRACT: Viewing soils in the full context of landscape ecology is imperative. Both land and its component soil resources are finite. The biological capability of the earth's ecosystems is limited, even though agricultural productivity has been manipulated by genetic selection of plants, adjusting nutrient flows, managing water, and controlling pests. However these interventions also have serious economic and environmental repercussions. Increasing populations require more space, more food, more fuels, and more of other resources. For soil scientists the challenges are to understand soil processes, characterize and map soil resources, and predict soil behavior under a variety of potential uses in the interest of providing society and its governing institutions with options and tradeoffs in land-use decisions. Global and regional economic and agricultural productivity will depend solely on our ability to increase productivity by: (a) making economic-agricultural development congruent with ecological and social-political realities, (b) ensuring proper use and conservation of indigenous genetic resources, and (c) rehabilitating disturbed and degraded ecosystems. In this review we assess the considerations and suggest needed strategies.

KEY WORDS: Soil quality, resource management

Namkoong, G. Boyle, T. Gregorius, H.R. Joly, H. Savolainen, O. Ratnam, W. and Young,A. 1996. "Testing Criteria and Indicators for Assessing the Sustainability of Forest Management: Genetic Criteria and Indicators." Working Paper 10. Center for International Forestry Research, Bogor, Indonesia. 12 pp.

ABSTRACT: This working paper contains proposals for specific genetic criteria and indicators (C&I) that are expected to be part of a more general set of biological C&I. These proposals are intended for use in guiding tropical forest management, but the indicators and verifiers we describe are not in the form of simple prescriptions where a single measurement can be recommended for a single causal effect. Since genetic dynamics operate at a different time and special scale than events that can be observed at the level of forest stand effects, a single forest stand event can have effects on several genetic processes. In addition the pattern of genetic diversity that has already evolved is due to a balance of several evolutionary forces that operate at different spatial and temporal scales, and forest practices would therefore be expected to affect several genetic factors. To provide guidance on what genetic processes may be affected by forest practices, we first describe the factors that affect genetic processes and then provide a matrix of relationships between types of forest-level events and genetically significant factors.

Since the intention of the larger project is to steer possible management actions, the report identifies two main concerns of sustainability: first, whether the genetic variation is being maintained, and second, what conservation or enhancement measures can be effective. We state one criterion and for each of these concerns sets of indicators are defined that would address the issue of sustainability. For each indicator, sets of verifiers are provided which differ in the biologically relevant feature they measure or in the precision and technical facilities they require.

Finally, the need for rapid assessment and precision under difficult field conditions requires research and development of efficient direct and surrogate measures of the genetic resource. We therefore include recommendations for short- and medium-term research that would improve the scientific value, cost-effectiveness, ease of use, and further development of genetic criteria and indicators.

KEY WORDS: Indicators (general), forestry

Narayanan, S. 1995. "Input Use Efficiency Indicator: Use Efficiency for Fertilizer, Pesticides and Energy." Report 11. Farm Economics Division, Policy Branch, Agriculture and Agri-Food Canada, Ottawa, ON. 22 pp.

ABSTRACT: This paper documents the development of input use efficiency indicators (plant nutrient), pesticide (plant protection), and energy inputs. Discussion includes general aspects of inputs and environment, policy context, rationale for input use efficiency indicators, methodology, data, and analyses of results.

NOTES:

Pillar: Viability
Indicator: Input use efficiency
Definition: Quantity of input used to produce a unit quantity of agriculture output
Scope: National, regional
Unit of measurement: Ratio of inputs over outputs is expressed as an index with the base year set at 100
Methods of measurement: Quantities of input and output were derived implicitly from expenditures and receipts data by deflating with appropriate price indexes. This approach overcomes the lack of actual quantity data for many inputs and output items and facilitates aggregation of inputs

and outputs measured in different units. Implicit quantity is also a legitimate measure as it is expressed in constant dollars and is proportional to and closely tracks the trends in absolute quantities.

Targets: The indicators cannot be assessed against a performance objective or standard because no such standard exists. Therefore the change and the direction of change in the indicators are used as a means for assessing the results.

Limitations: Implicit inputs, used in the derivation of the indicators, partially overcome the problem of lack of actual and consistent data and the aggregation of heterogeneous input items. But this limits direct comparison of total use and efficiency index levels between inputs and by commodity. Comparisons between regions for the same input is justifiable, provided the regional price deflators are weighted properly.

The indicators are aggregative and lumpy (separate ingredients are combined into one inputN, P, and K, fertilizers, and various pesticide compounds). This limits the scope of the indicator for policy interventions.

Input indicators in themselves do not provide quantitative explanations of the causes for the changes and trends in them, nor do they capture their indirect environmental impacts or benefits. These are explained qualitatively based on available extraneous information.

Conclusion:

Recommends:

1. Developing indicators by ingredient category and/or by crop

2. Establishing threshold/critical levels based on ensuring adequate output and defined by agroecological regions for each input ingredient

3. Developing separate energy efficiency use indexes by crop and livestock outputs

4. Developing input use efficiency indicators by converting fertilizer, pesticide, and energy inputs and outputs into standard energy units based on available conversion coefficients and then dividing the energy units of input by energy units of output to arrive at the indicators.

KEY WORDS: Viability, inputs

Natural Resources Conservation Service.1996. "Ecosystem Indicators: A Process to Assist with Planning and Monitoring Activities." U.S. Department of Agriculture, Washington, D.C. 37 pp.

SUMMARY: The Natural Resources Conservation Service (NRCS) assigned an "Action Team" the task of facilitating the use of indicators for planning and implementation activities within the agency. While the state-of-the-art in the use of indicators to assess ecosystem processes is not well advanced, there are some indicators that can be useful today. The team developed a model to direct the selection of indicators for use in evaluations of ecosystem conditions. The team also developed a preliminary set of indicators and recommendations for their further development and use. Additional analysis of indicators is needed by the NRCS Science and Technology Consortium.

Evaluations of ecosystem condition require responses to specific questions regarding the interrelationships and integrity of the system's soil, water, air, plant, animal, and human resources through the functioning of ecological processes within the system. Design of the Indicator Selection Model was directed by these concerns: What are the questions that need to be answered in evaluations of ecosystem condition? What are the attributes to measure that provide answers to these questions? How are the attributes measured (what indicator to use)?

The Indicator Selection Model is comprised of seven elements or levels:

1. Ecosystem Aspect: A broad grouping of environmental, ecological, and human community concerns that are common to all natural ecosystems

2. Framing Questions: The minimum set of diagnostic questions that need to be answered in comprehensive evaluations of ecosystem condition

3. Ecosystem Components: A listing of related environmental ecological, socioeconomic, cultural, or political factors considered to be important elements of an ecosystem

4. Assessment Questions: Those questions that are formulated in reference to the framing questions and their constituent ecosystem components

5. Indicators: The quantitative or qualitative assessments of ecosystem components that are needed in order to answer the assessment questions

6. Measurement: The approach used to measure the variable(s) to be assessed by the indicator(s)

7. Interpretation: The process used to interpret the measured values collected using the indicator and measurement.

Initial use of the model is made by entering the system at the first element and proceeding through the remaining levels. Continued application of the model to select additional indicators can be an iterative process, with re-entry at the appropriate level.

The Indicator Selection Model presented in this report is designed to guide stakeholders and resource planners to think beyond single resource issues and consider the condition of the larger ecosystem, including human dimensions of the system.

The report concludes with 10 recommendations for action by NRCS.

KEY WORDS: Indicators (general)

Neave, P. Kirkwood, V. and Dumanski, J. 1995. "Review and Assessment of Available Indicators for Evaluating Sustainable Land Management." Technical Bulletin 1995-7E. Centre for Land and Biological Resources Research, Agriculture and Agri-Food Canada, Ottawa, ON. 29 pp.

ABSTRACT: The need to determine whether current land management practices and agricultural systems are environmentally and economically Sustainable has led to the development of a framework for assessment of sustainable land management (SLM). Indicators of SLM can be grouped into four categories: physical, agronomic, economic and social. In this report some indicators are reviewed, and selected indicators are assessed using 1991 Census of Agriculture data.

Indicators were selected on the basis of criteria from the literature and availability of data. Indicators that appear useful in assessing sustainable land management include: historical trend of cropping intensity, nutrient budgets, physical land flexibility, yield variability, windbreak density, crop influence on soil quality, conservation tillage, historical trend of area in summerfallow, gross margin with and without government subsidies, and debt load.

NOTES:

The purpose of the study was to compile indicators available and suitable for FESLM assessments

KEY WORDS: Indicators (general), sustainable land management

Nieuwoudt, W.L. and De Jong, J.J. 1985. "Land Rents as Indicators of Profitability in Maize and Wheat Production." *Agrekon* 24: 2, 21-6.

ABSTRACT: Land rents can be used to monitor anticipated changes in farm profitability of a long-run nature. Rents also provide information on the relative profitability of various enterprises (opportunity cost principle), such as maize versus livestock.

During 1983-84 rents on grazing land in the Maize Triangle averaged at R6,85 per ha, maize land was at R31,28, while wheat land in the Eastern Free State rented at R24,14. Data show that the expected profitability of maize was substantially higher than that of livestock during the period studied. Using the concepts of economic rent and transfer earnings, data indicate that the comparative advantage of maize versus livestock production in the three principal maizeproducing areas is the same.

Since rents are determined by market forces, they could provide insight into the dynamic and anticipated changes in farming profitability.

NOTES:

Pillar: Viability
Indicator: Land rents
Description: The more profitable an enterprise the more rent a prospective tenant will pay for the use of the land, and the higher will be the rental required by the landowner to induce him to part with the use of his land. Scope: Local, regional, national
Crops: Maize, wheat, livestock
Location: South Africa: Western Transvaal, North Western Free State, Transvaal Highveld
Unit of measurement: US$/ha
Comments: Economic theory states that no maize farmer, for instance, will produce maize in the long run if his expected income per hectare from maize does not exceed his expected cost per hectare plus his opportunity income (cost) of producing the second-best crop. In the case of maize farming it has been argued that there are no alternative crops. In that case the opportunity cost is the use of the land for livestock farming, which is measured by rents of grazing land. In this study it was shown that rents on arable land are substantially higher than those on grazing land, implying that maize is more profitable than livestock on a per/ha basis. Because crop production is so risky in South Africa, farmers have losses in some years. This uncertainty, however, is reflected in the rents agreed upon where land is rented.

KEY WORDS: Viability, land rents

OECD. 1997. "Environmental Indicators for Agriculture." Organisation for Economic Co-operation and Development, Paris. 62 pp.

NOTES:

The OECD is in the process of developing agri-environmental indicators (AEIs) within the overall context of agricultural policy reform and the integration of environmental concerns into agricultural policies. OECD uses the Driving Force-State-Response (DSR) model for consistency with other indicator development efforts. The initial focus is on measuring the key environmental indicators for agriculture within the DSR framework, and then developing an understanding of the linkages between the indicators and me appropriate driving forces and responses in the broader context of the long-term sustainability of agriculture.

Thirteen priority agri-environmental issues have been identified by OECD member countries, for which relevant indicators are being developed:

Nutrient use
Pesticide use
Water use
Land use and conservation
Soil quality
Water quality

Greenhouse gases
Biodiversity
Wildlife habitats
Landscape
Farm management
Farm financial resources
Sociocultural issues.

KEY WORDS: Indicators (general)

OECD. 1996a. "Development of an Agricultural Nutrient Balance Indicator: Progress Report from Belgium." COM/AGR/CA/ENV/EPOC(96)84. Joint Working Party of the Committee for Agriculture and the Environment Policy Committee, Organisation for Economic Co-operation and Development, Paris. 49 pp.

NOTES:

Pillar: Viability
Indicator: Nutrient balance
Description: The gross nutrient balances of the total quantity of nitrogen (N) and phosphate (P), respectively, applied on agricultural land from the use of chemical fertilizers and livestock manure, minus the amount of N and P absorbed by agricultural plants
Purpose: An agricultural nutrient balance, which will be either negative or positive, can be used to assess whether an agricultural system releases nutrients into the environment or, to the contrary, brings about a net removal of nutrients from the environment. Most often nutrient balances are not useful indicators unless brought back to another unit, such as agricultural land area, total input of nutrients, or agricultural output.
Scope: Local
Farm type: Animal, crop
Unit of measurement: Difference between input and output of agriculture
Methods of measurement: Report provides a very detailed breakdown of input and output sources
Limitations: Indicator is dearly limited to nutrient losses from agricultural land, and does not take into account nutrient losses to the environment that may occur during other stages of agricultural production, such as animal production.

No provision was made for other possible inputs of nutrients such as deposition or biological nitrogen fixation.

Data sources: As far as losses from the land are concerned, both the surface balance and farm gate balance methods will provide similar results. Because of its relative simplicity the surface balance should be preferred when indicators based on these losses give sufficient answers to the problem. This would be the case, for example, when studying the implication of nutrient surpluses on ground water quality or when making comparisons between similar agricultural systems, such as between two grain-producing areas. But when indications are required on the contribution of agriculture to acid rain, the surface balance method will provide a rather incomplete picture.

The farm gate balance method seems to be more appropriate for comparisons between different agricultural systems.

KEY WORDS: Viability, nutrient balance

OECD. 1996b. "Development of an Agriculture and Wildlife Habitat Indicator: Progress Report from the United States." Joint Working Party of the Committee for Agriculture and the Environment

Policy Committee, Organisation for Economic Co-operation and Development, Paris. 33 pp. Room Document.

NOTES:

Pillar: Protection
Indicator: Wildlife habitat
Unit of measurement: Vertical Habitat Structure Index (VHSI) combined with land cover type

Measurement method: The VHSI was originally developed to estimate the effect of federal agricultural policies and practices on wildlife habitat in the U.S. Given that baseline conditions can be calculated for 1982 and 1992, it is now feasible to evaluate alternative policy scenarios by projecting shifts in land use or management and substituting those projected values into the VHSI to determine if the model changes and in which direction it would move.

Data to run the VHSI was obtained from the National Resources Inventory (NRI). This is a multiresource inventory of land use/cover, soil erosion, and agricultural practices on the nonfederal lands of the U.S. and is conducted at fiveyear intervals. NRI data are collected from stratified, clustered samples consisting of over 800,000 randomly selected points. Each NRI point has an associated weight, which permits the calculation of area estimates of various land use/ cover or resource attributes. VHSI output was calculated as the weighted mean index value for each Major Land Resource Area. The VHSI has been determined for both the 1982 and 1992 NRI samples.

Testing of the VHSI has been conducted with diversity indices (representing alpha diversity) calculated from the National Biological Survey's Breeding Bird Survey. VHSI explained 34 percent of the variance in an index of avian community integrity (birds observed/birds expected), but when spatial attributes were added to the model it explained 63 percent of the variance ($p<0.0001$). Other research has reported that the VHSI explained 70 percent of the variance in avian community dominance ($p<0.0001$).

Limitations: The model seems to perform well with natural classes of vegetative physiognomy, but the interpretations for agricultural practices are thus far subjective.

KEY WORDS: Protection, biodiversity

OECD. 1996c. "Development of Pesticide Use Indicator: Progress Report From Japan." Joint Working Party of the Committee for Agriculture and the Environment Policy Committee, Organisation for Economic Co-operation and Development, Paris. 8 pp. Room Document.

NOTES:

Pillar: Viability
Indicator: Pesticide use
Scope: Local
Unit of measurement: Risk x amount of use
Method of measurement: The risk to the environment is decided by the hazard of the pesticide itself and the potential for exposure. Both need to be incorporated into an evaluation of risk.
Therefore, it is possible to assume:

Hazard X Potential for Exposure = Risk.

To calculate risks, the representative factors of each (hazard, potential for exposure) must be examined and indices must be made.

Hazard:
- Toxicity
- Ecological toxicity
- Bioaccumulation

Potential for exposure:
- Persistency (degradability)
- Mobility
- Temperature
- Method of use
- Detection in water

Report provides concrete examples of classification methods for each factor.

KEY WORDS: Viability, inputs, pesticide use

Pagiola, S. and Dixon, J. 1997. "El Salvador Rural Development Study." Report 16253-ES. World Bank, Washington, D.C. 22 pp.

SUMMARY: The report consists of two parts, as summarized below.

Evidence of Land Degradation: Despite the availability of data from the FUSADES survey, it remains difficult to ascertain the extent and severity of land degradation problems in El Salvador. Nevertheless, it seems clear that catastrophic statements such as "75 percent of the country's surface is degraded'" are substantially exaggerated.

Extent of degradation. A more plausible order of magnitude is that about 50 percent of fields on moderate slopes and 80 percent of fields on steep slopes experience erosion, and that about onethird of fields on moderate slopes and two-thirds of fields on steep slopes experience productivity problems. Since fields on moderate and steep slopes account for about 30 percent and 10 percent of surveyed fields, respectively, the total area affected is much smaller than 75 percent of the country's surface. Important, also, is the likelihood that the sample may over-represent fields on steep slopes and less favorable soils. Another way to express this result is that about onequarter of farm fields are affected by erosion, and about one-fifth of farm fields are affected by productivity problems.

Severity of degradation. Unfortunately available data are insufficient to arrive at even order of magnitude estimates of the severity of degradation, except to note that, to date, it seems to have been possible to overcome its effects by increases in input use.

Regionally, the areas most affected appear to include those in the northern and eastern part of the country (the usual suspects) as well as sections of the western part of the country.

Causes of land degradation. Many farmers employ a range of conservation practices, but many do not. The available data do not allow definitive answers to the reasons for some farmers' failure to adopt conservation measures. It does seem clear that many of the conservation measures that have been promoted, particularly the more expensive structural measures, may not be costeffective for farmers. Conversely on steep slopes cultural measures, though cheap, may not be sufficiently effective. There may, therefore, be a need for additional research on cost-effective conservation techniques, particularly for farmers on steep slopes. That many conservation measures are not cost-effective from the farmers' perspective has been established in many instances throughout the world. Available data do not allow estimates of how many farmers have adequate measures available to them and yet fail to adopt them. In these instances neither ignorance nor

lack of credit seem likely to play important roles in the failure to adopt conservation measures. Rental regimes may well provide low incentives to conserve, but they only affect a relatively small proportion of all fields. Whether, and in what way, poverty affects conservation decisions remains to be established.

Even though conservation measures are relatively widely adopted, interventions to increase adoption might be justified if constraints or market failures mean farmers under-invest in soil conservation, In El Salvador the main constraints to farmer adoption of soil conservation are usually identified as farmer ignorance, insecure tenure, lack of credit, and poverty.

Ignorance. Ignorance is unlikely to be a constraint. Many farmers use various forms of conservation, showing that these are widely known.

Tenure. Farm households own three-quarters of the fields and almost 90 percent of the land they operate, so the impact of tenure problems is likely to be limited. Although there are reasons to expect rental practices to result in under-investment in conservation, primarily because of the short length of most leases, the survey reveals that conservation measures are in fact used on rented lands; indeed, a greater proportion of rented fields than of owned fields use cultural conservation measures.

Credit. None of the farmers in the survey had asked for credit to finance conservation measures, although many sought credit for other purposes, so credit is unlikely to be an important constraint.

Poverty. Available data are insufficient to determine whether poverty is an importanc constraint to investments in conservation.

The available evidence, although insufficient to allow a full cost-benefit analysis of the profitability of conservation measures under different conditions, does suggest that farmers make appropriate conservation decisions given the severity of the threats they face and the cost and effectiveness of different conservation measures.

NOTES:

Pillar: Protection
Indicator: Erosion, adoption of conservation measures
Scope: El Salvador
Unit of measurement: Qualitative

KEY WORDS: Erosion, El Salvador, conservation measures

Pierce, F.J. Larson, W.E. Dowdy, R.H. and Graham, W.A.P. 1983. "Productivity of Soils: Assessing Long-Term Changes Due to Erosion. *Journal of Soil and Water Conservation* 38:1, 3944.

ABSTRACT: An approach to evaluating the long-term effects of erosion on the productive potential of the U.S. soil resource base is presented. This approach involves the application of a numerical index method for quantifying productivity to soil and land-use data bases compiled by the Soil Conservation Service. The relativeproductive potential of soil was evaluated in terms of the environment it provides for root growth based upon the soil's available water capacity, resistance to root growth and development, and adequacy of pH to a depth of 100 centimeters (39.4 inches). The productivity of soils in Major Land Resource Area (MLRA) 105 in Minnesota now and after 25,50, and 100 years of erosion was calculated using erosion rates reported in the 1977 National

Resource Inventory. The results indicated that the weighted average reduction in soil productivity was less than 5 percent for soils within this MLRA, with the greatest reduction occurring on soils having slopes that exceed 6 percent.

KEY WORDS: Soil quality

Pierce Colfer, C.J. Prabhu, R. and Wollenberg, E. 1995. "Principles, Criteria and Indicators: Applying Ockham's Razor to the People-Forestry Link." Working Paper 8. Center for International Forestry Research, Bogor, Indonesia. 16 pp.

ABSTRACT: This concept paper addresses those elements in the people-forest interface that we perceive as critical to sustainable forest management, based on our own training and experience, as well as two field tests of the conceptual framework (in Kalimantan and Cote dTvoire). Initially, we define our use of important terms, like sustainability, well-being/needs, and people; and make clear some of our assumptions. We briefly allude to four pertinent conceptual and policy issues, including the role of people in relation to the forest; the significance of maintaining cultural diversity; the relationships among cultural integrity, culture change, and stakeholder participation; and finally, policy issues pertaining to land use, population, and people's participation. The body of the paper discusses two principles, each with three associated criteria. An appendix lists principles, criteria, indicators, and some verifiers found useful in our field tests. We conclude briefly by describing future research plans, focused on refining our definitions of stakeholders, testing the importance of intergenerational access to resources and people's participation in sustainable forest management, and testing the applicability of such criteria and indicators for community forestry contexts.

KEY WORDS: Indicators (general), forestry

Pierce Colfer, C.J. Woelfel, J. Wadley, R.L. and Harwell, E. 1996. "Assessing People's Perceptions of Forests in Danau Sentarum Wildlife Reserve." Working Paper 13. Center for International Forestry Research, Bogor, Indonesia. 23 pp.

ABSTRACT: Previous research identified three important issues of relevance to forest people's roles in sustainable forest management, which we address here: the presence of a "conservation ethic," a feeling of closeness to the forest, and a significant forest-culture link. In this paper we examine a method (the Galileo), recently pretested for this purpose in West Kalimantan, which we hope can help to assess such issues quickly, reliably, and in a quantitative manner amenable to use by would-be assessors of various educational and experiential levels. We describe the method, suggest improvements for future tests, and present some illustrative findings from West Kalimantan. We conclude with questions that emerged during our pretest and others that remain for subsequent research.

NOTES:

Pillar: Acceptability
Indicator: Conservation ethic, feeling of closeness to forest, forest-culture link
Location: West Kalimantan
Scope: Local
Unit of measurement: Cognitive distance
Method of measurement: Using a conventional Galileo study, researchers asked participants to use the distance between "black" and "white" as a measuring stick in comparing on a scale of

1-to-10 each of paired concepts; for example, fish, wood, rattan, honey, garden, future, forest, animal, good, spirit, water, man, village/home, fire, and so forth.

KEY WORDS: Acceptability, forestry

Pieri, C. Dumanski, J. Hamblin, A. and Young, A. 1995. *Land Quality Indicators.* World Bank Discussion Paper 315. World Bank, Washington, D.C. 51 pp.

ABSTRACT: Maintenance of the productive potential of land resources and checking of land degradation is a fundamental element of sustainable land use. For this to be achieved, there is a fundamental need for indicators of land quality, the condition of "health" of land. Land quality indicators are similar to economic and social indicators already in use. It is only by means of indicators that changes in land quality can be monitored and policy or management action taken. A global coalition of international and national institutions, led by the World Bank, FAO, UNEP, and UNDP are developing a system of land quality indicators for this purpose, concentrating in the first instance on productive agroecosystems.

A conceptual framework for land quality indicators is set out. The Pressure-State-Response (PSR) framework, previously developed as a basis for environmental indicators of pollution, provides a means by which land quality can be related to policy management. Land quality indicators are therefore of three kinds: indicators of pressure upon land resources, of changes in the state of land quality, and of responses by society to these changes. Indicators can be assessed within the context of major land issues; these comprise inappropriate land-use systems, land degradation, and inadequacies in the policy environment for land users.

Land quality indicators can be applied at different scales, including farm, local, district, national, and international. The present effort is focused on indicators for application at district (project) and national/international scales. Indicators have particular applications first, in development projects, both sectoral and in the area of natural resources management; second, with respect to the effects of national policies on land quality; and third, for determination of policy priorities at the international level.

Two groups of examples of land quality indicators are given. The first is based on results from two regional workshops, aimed at identifying key land issues and appropriate indicators for some major agroecological zones of the tropics and subtropics. The second group sets out pressure, state, and response indicators applicable to major problems of land degradation.

Sources of data and information of indicators are reviewed. There is considerable scope for making use of existing data sources, appropriately combined and standardized as indicators. There are also substantial data gaps, notably in the areas of monitoring soil changes and the effects of land management practices. In addition to databases, use can be made of modeling and of the local knowledge of farmers.

A program of work is outlined for the development of cost-effective ways of obtaining internationally agreed upon sets of land quality indicators. Pilot studies in major agroecological zones will form an important element. Because of the urgency of the situation, initial activities will be based on making best use of existing methods and sources of data. This will show where gaps in knowledge exist, and work can then progress towards the collection of new information.

KEY WORDS: Indicators (general), land quality

Prabhu, R. Colfer, C.J.P. Venkateswarlu, P. Tan, L.C. Soekmadi, R. and Wollenberg, E. 1996. *Testing Criteria and Indicators for the Sustainable Management of Forests: Phase 1Final Report.* CIFOR Special Report. Center for International Forestry Research, Jakarta, Indonesia. 217 pp.

NOTES: This report is the first phase of CIFOR's research project on testing criteria and indicators (C&I) for the sustainable management of forests, which was initiated in August 1994. The project has sought to identify reliable, relevant, and cost-effective C&I based on field evaluation of existing sets under forest management unit (FMU) conditions in Germany, Indonesia, Côte d'Ivoire, and Brazil. These evaluations were carried out using an interdisciplinary and iterative approach developed by the project. The method is based on balancing the use of an interdisciplinary team of experts in consultation with relevant stakeholders to evaluate C&I within the frame of reference of a particular FMU. It has also been used successfully in an independent test carried out in Austria.

Results from the field tests in Brazil, Côte d'Ivoire, and Indonesia suggest that more than half of the C&I related to policy and legal frameworks, ecological impacts, and production aspects were common to all three sites. There was, however, a marked and sharp decrease in this level of commonality when it came to C&I related to the social aspects of forest management. Comparisons of these results with those obtained from the test in Austria reveal that most of the C&I identified as being common to the three tropical sites were also listed in the Austrian set. This suggests that at least in closed-forest formations, the development of a common 'core' set of C&I seems possible; however, site-specific elements will remain important, particularly for social aspects and lower levels of hierarchy such as verifiers.

Policy
Principle: Policy planning and institutional framework are conducive to sustainable forest management
Criterion: There is a sustained and adequate funding for the management of forests
Indicators:

- Policy and planning are based on recent and accurate information
- Effective instruments for intersectoral coordination on land use and land management exist
- There is a permanent forest estate (PFE) adequately protected by law, which is the basis for sustainable management, including both protection and production
- There is a regional land-use plan or PFE, which reflects the different forested land uses, including attention to such matters as population, agricultural uses, conservation, environmental, economic, and cultural values
- Institutions responsible for forest management and research are adequately funded and staffed

Ecology
Principle: Maintenance of ecosystem integrity
Criterion: Ecosystem function is maintained
Indicators:

- No chemical contamination to food chains and ecosystem
- Ecologically sensitive areas, especially buffer zones along water courses, are protected
- No inadvertent ponding or waterlogging as a result of forest management
- Soil erosion is minimized

Criterion: Impacts to biodiversity of the forest ecosystem are minimized
Indicators:

- Endangered plant and animal species are protected
- Interventions are highly specific, selective, and confined to the barest minimum
- Canopy opening is minimized
- Enrichment planting, if carried out, should be based on indigenous, locally adapted species

Criterion: The capacity of the forest to regenerate naturally is ensured

Indicators:

Representative areas, especially sites of ecological importance, are protected or appropriately managed
Corridors of unlogged forest are retained

Social Environment
Principle [implied]: Forest management maintains fair intergenerational access to resources and economic benefits
Criterion: Stakeholders'/forest actors' tenure and use rights are secure

Indicators:

Tenure/use rights are well defined and upheld
Forest-dependent people share in economic benefits of forest utilization
Opportunities exist for local/forest-dependent people to get employment and training from forest companies

Principle [implied]: Stakeholders, including forest actors, have a voice in forest management
Criterion: Stakeholders/local populations participate in forest management
Indicators:

Effective mechanisms exist for two-way communication related to forest management among stakeholders
Forest-dependent people and company officials understand each other's plans and interests

Criterion: Forest-dependent people/stakeholders have the right to help monitor forest utilization
Indicator:

Conflicts are minimal or settled

Production of Goods and Services
Principle: Yield and quality of forest goods and services are sustainable
Criterion: Management objectives are clearly and precisely described and documented
Indicator:

Objectives are clearly stated in terms of the major functions of the forest, with due respect to their spatial distribution

Criterion: A comprehensive forest management plan is available
Indicators:

Maps of resources, management, ownership, and inventories available
Silvicultural systems prescribed and appropriate to forest type and produce grown
Yield regulation by area and/or volume prescribed
Harvesting systems and equipment are prescribed to match forest conditions in order to reduce impact

Criterion: The management plan is effectively implemented
Indicators:

Preharvest inventory satisfactorily completed
Infrastructure is laid out prior to harvesting and in accordance with prescriptions
Reduced impact felling specified and implemented
Skidding damage to trees and soil minimized

Criterion: An effective monitoring and control system audits management's conformity with planning
Indicators:

Continuous forest inventory plots established and measured regularly

Documentation and records of all forest management activities are kept in a form that makes it possible for monitoring to occur

Worked coupes are protected (for example, from fire, encroachment, and premature reentry)

Tree marking of seed stock and potential crop trees

KEY WORDS: Indicators (general), acceptability, biodiversity, forestry, protection, viability, productivity

Quiroz, C. 1996. "Local Knowledge Systems Contribute to Sustainable Development." Centre for International Research and Advisory Networks, Enschede, The Netherlands. World Wide Web http://www.nuffics.nl/ciran/ikdm/401/articles/quiroz.html

ABSTRACT: The value of local knowledge systems in facilitating development is gradually being recognized by national and international development agencies. Nevertheless these systems are not yet familiar to many professionals working in agricultural and rural development. This article presents a literature review of local knowledge systems in Latin America that are capable of contributing to sustainable development approaches in the region.

KEY WORDS: Indigenous knowledge

Sahara and Sahel Observatory. 1997a. "Implementation and Impact Indicators for the Convention to Combat Desertification." Observatoire du Sahara et du Sahel, Paris. 34 pp.

ABSTRACT: The Convention to Combat Desertification (CCD) laid special stress on the need to monitor and evaluate desertification control activities. Many of the provisions in this legal tool focus on the question of monitoring indictors for achievements in CCD implementation and the combat against desertification.

After defining various concepts (indicators, parameters, indices, benchmarks), the document looks more closely at two types of CCD-related indicators, CCD implementation monitoring indicators and impact indicators.

The CCD implementation monitoring indicators were devised as a performance grid for all National Action Program (NAP) actors and, as such, should fit in with the various phases of NAP design and implementation and report the quality of the process adopted, especially the application of the participation and partnership principles.

The proposed indicators are compiled in a matrix that defines the individual indicator's evaluation parameters and its significance to the NAP process. The indicators have to be fashioned to respond to national priorities and specificities. At a later stage they will be validated through field tests at the national level as part of the CCD implementation monitoring mechanism.

At the international level an analysis of work on the concept of impact indicators shows that numerous institutions and organizations have studied the concept to meet their own particular needs, but that once prepared, the impact indicators have not been validated or tested in the field.

Final recommendations for further work on CCD implementation indicators bear particularly on the need for field testing and validation and ways to use these indicators in preparing national reports for the Conference of Parties.

An appropriate methodology, based on an analysis of land degradation and actions to combat desertification, should be used in the approach to impact indicators. The indicators should be crafted as decision-support tools for different groups of people working on desertification control.

Last, there are special recommendations urging the CCD Science and Technology Committee to give priority to actions on indicators.

NOTES:

Pillar: Productivity, protection
Indicators: Good selection of institutional, implementation, and impact indicators
Scope: National, global
Unit of measurement: Varied

KEY WORDS: Indicators, evaluation, monitoring, desertification, performance, impact

Sahara and Sahel Observatory. 1997b. "Impact Indicators and Monitoring-Evaluation for Action Programmes to Combat Desertification." Observatoire du Sahara et du Sahel, Paris. 27 pp.

ABSTRACT: The OSS workshop on CCD indicators (Paris, 1720 June, 1997) for experts from countries and organizations involved in CCD implementation focused on the following question: What procedure should be used to develop a consensual approach to evaluating the effects of the CCD? The workshop, in keeping with the spirit of the resolution on benchmarks and indicators adopted by INCD in January 1997, felt it was urgent to reflect on actions and provisions needed to consolidate a sustainable monitoring-evaluation system that could be controlled at the national level in affected countries. It is crucial for work on the best adapted conceptual models for the development of CCD impact indicators to fit in with the prospective "internalizaton" of the monitoring-evaluation function at the National Action Program (NAP) level as an ongoing activity, fully integrated into the CCD process.

This leads to several basic questions whose answers could structure sustainable cooperation between the different categories of actors involved, from the local to the national level.

What Are the Different Forms of CCD Monitoring and Evaluation?

Participating actors should be able to measure CCD implementation and its impact on solving the problem. In other words, they need indicators.

The CCD and work by INCD have established three complementary forms of monitoring:

Monitoring CCD implementation, which has already led to the preparation of an indictors matrix on CCD implementation

Monitoring desertification, in order to obtain more thorough knowledge of desertification as a phenomenon

Monitoring the effects of the CCD through impact indicators.

To obtain an overall view of the NAP implementation process requires a combination of these three monitoring activities.

Because of the integrative character of the NAPs, it will be necessary to define a monitoringevaluation system that measures the effects of all programs designed to benefit populations affected by drought or desertification. Experiences in numerous monitoring-assessment projects show the uselessness of seeking a direct, single cause and effect relationship. It would be more appropriate to use a dynamic approach to the monitoring-evaluation system, in order to be able to stake out reference marks and ensure coherence among strategic frameworks. Coherence of this type could be sought as part of the global objectives defined in Rio in 1992; that is, striving for sustainable develepment.

Indicators: Which Users and What Needs?

Establishing indicators as part of national monitoring-assessment mechanisms will provide a formidable opportunity for developing dialogue and consultation and for working toward con-

sensus among participating actors. This, indeed, involves identification of the specific objective-related needs of the various categories of participating actors. The procedure should be supported by an assessment methodology framework that:

Makes it possible, by using impact indicators, to reach a consensus on the NAP objectives and how to assess its effect

Defines the actors' information needs and the appropriate information collection, processing, and dissemination methods and tools

Gradually, harmonizes and improves the national environmental information mechanism

What Lessons Can Be Learned from Experience with Desertification Indicators and Impact Indicators?

Considerable research has been conducted on methodologies and indicators applied to soil degradation/quality, biomass production, biodiversity, water quality, and so forth. This research has served as the basis for assessing the state of natural resources at the local, national, and regional levels. However, we did not come across any experiences with systems for monitoring and evaluating the impact of programmes at the national level.

A precise definition cannot be derived from an off-site exercise. Since the impact indicators are closely connected to the NAP objectives and to the process-related needs, they have to be developed at the national level by the participating actors themselves.

At the level of international cooperation the main guidelines and objectives of the monitoring-assessment mechanisms should be defined. But time and again experience has shown that the performance of the monitoring-evaluation mechanisms is closely related to the degree of the participating actors' involvement from the very earliest stage: Who develops the indicators, at what level, and what is the role of off-site reflection?

A monitoring-evaluation framework has to be installed gradually and will depend largely on national capability and the quality of and methods for processing available information. This is an evolving process that should contribute to improving exchange relations between the main NAP actors.

What Should Be the Roles of the Participating Actors, from the Local to the International Level?

As concerns national actors, the state has prime responsibility in coordinating actions carried out under the NAP. The CCD sees this task as one that devolves essentially on the National Coordination Unit (NCU), which plays a leading synergetic role in NAP monitoring and assessment. For reasons of quality and relevance, indicators selected must be conceived with the effective participation and involvement of the various categories of actors concerned with the NAP process.

One of the best ways to integrate technical support services and scientists in the NAP monitoring process would be to establish a permanent environmental monitoring mechanism, somewhat like an observatory, at the national level. This mechanism could become the main channel for national scientific capacity building and a tangible way to develop international cooperation and scientific exchanges.

Appropriate subregional, regional, and international organizations, international institutions, and cooperating developed partner countries should strive to:

Obtain a more thorough understanding of scientific concepts and approach methodologies for indicators

Participate in experience-sharing in this field

Provide the states with scientific, technical, and financial support

Help these states jointly test selected models.

Cooperating partners should give priority to this part of the NAPs in order to mobilize scientific, technical, and financial means for the scientific communities in the affected countries.

In this context, the Scientific and Technical Committee would have an important role to play, in particular in:

Making a critical analysis of current experiences related to indicators

Drawing up an inventory of knowledge to be used as support in the preparation of indicators

Studying and proposing a harmonized methodological frame for formulating CCD indicators.

Finally, the working group stressed the fact that this process provides an opportunity for all partners to strengthen dialogue and information and increase their understanding of the CCD.

Monitoring-Evaluation: At What Cost?

Efforts to minimize the cost of producing impact indicators should start with simple indicators that do not need excessively complex, costly research. These indicators could be refined at a later time, when the national capacity for data collection and processing has been further developed.

The state's definition of a coherent framework for action in this field will constitute a substantial source of savings. It can be used to avoid duplication, optimize national scientific and technical capacities, and better orient financial and technical support from cooperating partners.

In any case monitoring-evaluation costs should be included in the global assessment of resources needed for NAP implementation.

NOTES: The report provides a good overview of the most important activities in developing indicators.

Pillars: Productivity, protection
Indicators: Varied, mostly project and impact indicators
Scope: National
Unit of measurement: Varied

KEY WORDS: National action plans, NAP, monitoring, evaluation, desertification, implementation, impact

SCARM. 1996. "Indicators for Sustainable Agriculture: Evaluation of Pilot Testing." Standing Committee on Agriculture and Resource Management, Canberra, Australia. 36 pp.

NOTES:

Pilot testing of the efficacy of the attributes of indicators of sustainable agriculture recommended in SCARM Report 51 has been conducted for a variety of agricultural systems and regions, namely:

Dryland grazing and cropping in the Upper Condamine, Queensland

Dairying in the Farm North coast. New South Wales

Irrigation farming in the Goulburn Valley, Victoria

Dryland cropping in the Mallee, south Australia

Pastoral wool industry in shrublands in the Gascoyne region, western Australia

Extensive pastoral beef industry, Victoria River District, northern Territory.

The pilot trials were strongly directed toward the Expert Group approach. The participants were also mindful of other monitoring programs such as State of Environment Reporting, National Greenhouse Gas Inventory, and National Water Quality Monitoring Strategy and integrated attributes and data sources with these programs as much as possible to avoid duplication and reduce cost.

For each area/farming system the proposed attributes were evaluated according to a set of criteria,including their relevance to the needs for state/territory and national level reporting and decisionmaking and types of data available for their measurement. The criteria found to be most important in determining the effectiveness of an attribute were the availability of valid, reasonably low cost, and regularly collected data and the ability to assemble these data sources at regional, state, and national levels.

Data availability was identified as a major hindrance to the successful outcome of the indicators project. The availability and quality of data vary greatly between attributes and, for a given attribute, between individual regions, states, and agencies. Data will come from a number of sources, but a large proportion will be supplied by Australian Bureau of Statistics (ABS), and Australian Bureau of Agricultural and Resource Economics (ABARE). Provision of sufficient data at a regional scale is necessary for satisfactory estimation of the attributes, and negotiating that outcome with key data providers was identified as a high priority for the next stage of the indicators work. It will also be necessary to devise protocols to ensure consistency in the reliability of the data and the terminology, methodology, and analyses used for reporting.

Appropriate datasets were available for a number of the proposed attributes, particularly those measuring economic and social indicators. In contrast, land and water quality and off-site environmental indicators are derived from biophysical parameters.

Land and Water Quality to Sustain Production

The pilot trials showed that there is a general need for more work on environmental attributes, particularly those related to water balance, biological resilience, chemical contamination, river outfall, turbidity, frequency of dust storms, and length of contact zone. Participants advocated that some of these attributes be replaced, and others received further development with experts in appropriate disciplines. Testing of new attributes will need to be undertaken at the earliest opportunity.

Pillar: Protection
Indicator: Water use efficiency of crops/livestock
Scope: Local
Methods of measurement: Water-use efficiency can be estimated for dryland cereal cropping. This data would come from ABS Agricultural Census on a statistical local area (SLA) basis and from the Bureau of Meteorology (rainfall) on a meteorological station basis. Similar methodology may be used in irrigation areas, although the group suggested that the value of production (rather than weights of production) be considered as a term in the equation. This suggestion needs to be evaluated. There are also significant limitations to its use for noncereal crops. There is also uncertainty regarding its usefulness when the data are aggregated across a region.

Consequently, a number of other attributes to capture regional water balance were suggested. These included groundwater and stream flow monitoring and warrant further consideration.

Pillar: Viability
Indicator: Nutrient balance
Scope: Local, regional, national
Unit of measurement: A statement of the difference between inputs of elemental nutrients applied as fertilizers and outputs (nutrients exported in produce) was recommended.
Methods of measurement: Production weights can be obtained from the ABS Agricultural Census on an SLA basis. Fertilizer inputs can be obtained from the same source, although data availability varies between years. Additional data on product sales may be obtained from fertilizer companies and ABARE to give a breakdown of elements in the fertilizers applied. However, consistency in data collection and type of information is seen as essential for the successful evaluation of this indicator.

Pillar: Protection
Indicator: Biological resilience
Scope: Local, regional, national
Methods of measurement: The concept of biological resilience was considered to include both resilience within production systems and within the landscape. To measure the former, enter-

prise diversification was suggested as a new attribute. For the latter the earlier proposed attributes (areas and degree of fragmentation of native vegetation) were expanded to include rangeland condition and condition of remnant vegetation.

Enterprise diversification requires a precise definition before its suitability can be evaluated. Its measurement could come from economic data such as total receipts for a farm and the contribution of each enterprise to the total. Such data would be available from the ABS Agriccultural Finance Survey and ABARE Farm Surveys. Another possibility would be to use a classification system based on type of farm and production methods.

Area and condition of remnant vegetation and rangeland conditions are available at different levels of precision from state/territory land management agencies and from databases assembled by a number of other groups (for example, the national Greenhouse Gas Inventory).

Another attribute recommended for inclusion was change in area of productive land, in order to measure the loss of productive agricultural land to nonagricultural land uses, such as urban encroachment. The data could come from cadastral databases and council rezoning allocations.

Long-Term Real Net Farm Income

Comments: Data for long-term net real farm income are mostly obtained by surveys of a sample of farmers (for example, farm financial data and surveys on participation and implementation). Thus the principal restraint is how disaggregated the analysis can be. These indicators may therefore only be achievable in an industry by state/territory format.

Pillar: Viability
Indicator: Net farm income
Scope: Regional, national
Methods of measurement: A valid attribute for which data are available from ABS and ABARE. However, sample size may limit its interpretation at the regional level. Work is needed to determine the sampling density required for statistically robust regional assessments.

Pillar: Viability
Indicator: Productivity
Scope: Regional, national
Methods of measurement: A combination of ABS and ABARE data sources were considered most suitable, although sample size at the regional level may again be a limitation.

Pillar: Viability
Indicator: Terms of trade
Scope: National
Methods of measurement: Data available from ABARE at state and national scales. It cannot be disaggregated to regional scales.

Pillar: Viability
Indicator: Number of farms
Scope: Local, regional, national
Methods of measurement: Apart from problems associated with definition of 'farm,' data are available from the ABS Agricultural Census at the statistical, local area level and thus easily aggregated to regions.

Managerial skills

Comments: For the managerial skills indicator the data are mostly obtained by surveys of a sample of farmers. Thus the principal restraint is how disaggregated the analysis can be. These indicators may therefore only be achievable in an industry by state/territory format.

Pillar: Acceptability
Indicator: Farmer education level
Scope: Local, regional, national
Methods of measurement: Data on farmer education levels are readily available from the ABS Population Census. Further work is needed on appropriate postsecondary education categories.

Pillar: Acceptability

Indicator: Participation rate
Scope: Local, regional, national
Methods of measurement: The Landcare Attitude Index was expanded to include participation in the Property Management Planning initiative, which then subsumed the Farm Planning Capacity attribute. The new combined attribute was termed Participation Rate.

ABARE, ABS, and state/territory data would be available, but sample size may be a constraint for analysis at a regional scale.

Pillar: Acceptability
Indicator: Implementation of sustainable management practices
Scope: Local, regional, national
Methods of measurement: Measured as the adoption rate of a 'basket' of identified sustainable management practices, using ABS Agricultural Census and ABARE farm survey data

KEY WORDS: Protection, viability, acceptability, water quality, soil quality, education level, biodiversity, nutrient balance, emissions

Shultink, G. 1992. "Evaluation of Sustainable Development Alternatives: Relevant Concepts, Resource Assessment Approaches, and Comparative Spatial Indicators." *International Journal of Environmental Studies* 41: 34, 203-24.

ABSTRACT: Environmental, social, and cultural factors are increasingly recognized as affecting the long-term viability of development initiatives. The application of selected ecological concepts and a "systems approach" to resource assessment is suggested to improve understanding of environmental constraints and impacts, while providing a more realistic framework for comprehensive land evaluation. This approach includes the analysis of socioeconomic, technological, and cultural indicators in a spatial and temporal framework supported by geographic information systems and relevant performance or risk/impact assessment models. To provide a spatial comparative perspective the use of a single composite indicator is suggested, reflecting economic development opportunities, realistic constraints, and impacts. The derived comparative index may be used to provide a long-term, spatial, and comparative perspective of economic development opportunities by improving project appraisals and the selection of viable and sustainable development strategies.

KEY WORDS: Indicators (general), sustainable land management

Smaling, E.M.A. 1993. "The Soil Nutrient Balance: An Indicator of Sustainable Agriculture in Sub-Saharan Africa," *Proceedings of The Fertiliser Society*, 340. The Fertiliser Society, London.

ABSTRACT: The majority of agricultural systems in sub-Saharan Africa can be labeled "nonsustainable." An important, quantifiable indicator of sustainability is the nutrient balance of

such systems. The sum of nutrient inputs can either exceed, equal, or be lower than the sum of the nutrient outputs. Sub-Saharan Africa falls largely into the latter category. Macronutrient balances calculated at the supranational level (sub-Saharan Africa) and at the district level in Kenya reveal that nutrient mining has indeed become a serious problem in sub-Saharan African agriculture. Several options are discussed to alleviate nutrient mining. A number of recent interventions in the Kenyan district are elaborated, including zero-grazing, agroforestry, and soil conservation measures. Finally, particular attention is given to the possible role of mineral fertilizers in safeguarding both short-term productivity and long-term sustainability.

NOTES:

Pillar: Viability
Indicator: Nutrient balance
Description: The sum of nutrient inputs can either exceed, equal or be lower than the sum of nutrient outputs.
Location: Sub-Saharan Africa, Kenya
Scope: Regional, national
Unit of measurement: Numeric value
Method of measurement: Sum of total inputs minus the sum of total outputs
Inputs: Application of mineral fertilizer, application of organic manure, atmospheric deposition, biological nitrogen fixation, and sedimentation from natural flooding and irrigation water
Outputs: Removal of harvested product, removal of crop residues from the arable field, leaching, gaseous losses, and water erosion
Threshold: If calculation yields a negative number, depletion of the soil is taking place
Limitations: Quantitative information for some measurements were scarce and unevenly distributed in the region.

KEY WORDS: Viability, nutrient balance

Smith, W.N. Rochette, P. Monreal, C. Desjardins, R.L. Pattey, E. and Jacques, A. 1995. "Agroecosystem Greenhouse Gas Balance Indicator: Carbon Dioxide Component." Centre for Land and Biological Resources Research, Research Branch, Report 13. Agriculture and Agri-Food Canada, Ottawa, ON. 26 pp.

ABSTRACT: The objective of this study was to estimate the rate of change of carbon content in agricultural soils in Canada at the landscape level and to discuss potential and limitations of using a model to calculate carbon change across contrasting soil, climate, and cropping conditions encountered in Canada.

NOTES:

Pillar: Protection
Indicator: Agroecosystem greenhouse gases (GHG) balance
Description: Tracks the accumulation and release of the principal greenhouse gases from the agricultural sector and reports the net integrated balance
Scope: Local
Unit of measurement: Net emissions and uptake of each greenhouse gas expressed as tons per year. The integrated GHG balance will be expressed as tons of CO_2 equivalent units.
Methods of measurement: Century, a site-specific computer simulation model makes use of simplified relationships of soil-plant-climate interactions to describe the dynamics of soil carbon and nitrogen in grasslands, crops, forests, and savannas. It accounts for several management prac-

tices including planting, fertilizer application, tillage, grazing, and organic matter addition. Century simulates above- and below-ground phytomass production as a function of soil temperature, available water, and nutrient availability.

Researchers found the Century model to be useful to quantify the change in organic carbon in soils over the last 85 years. In the future they plan to use it to forecast level of carbon in agricultural soils associated with changes in management practices, such as a shift towards more forage crops, more intensive use of fertilizers, less summerfallowing, or a reduction in tillage. Micrometeorological techniques can be used to verify model predictions for all these scenarios, but because of the temporal variability of soil processes measurements must be collected through several annual cycles.

Future work: Changing a cultural practice in order to increase carbon sequestration in soils can also affect the fluxes of other greenhouse gases, such as CH4 and N2O. Because of the considerably higher global warming potential of these gases as compared to CO2, the interrelationship between the sources and sink of these gases is very important. For example, there are a whole series of measures that, while they increase carbon sequestration, can also increase N2O emissions. DNDC, a model that predicts CO2 and N2O exchange, will be used to forecast the impact of various management practices on the net greenhouse gas emissions in CO2 equivalent. This model, which relies on episodic rather than average climatic drivers, will be validated for several case studies across Canada. It will then be used to obtain regional and national estimates of N2O emissions. The regional estimates will be validated using micrometeorological techniques.

KEY WORDS: Protection, emissions

Smyth, A.J. and Dumanski, J. 1993. "FESLM: An International Framework for Evaluating Sustainable Land Management." Discussion paper. World Soil Resources Report 73. Food and Agriculture Organization, Rome, Italy. 74 pp.

KEY WORDS: Framework for the Evaluation of Sustainable Land Management (FESLM), productivity, security, protection, viability, acceptability

Smyth, A.J. and Dumanski, J. 1995. "A Framework for Evaluating Sustainable Land Management." *Canadian Journal of Soil Science* 75: 4, 401-6.

ABSTRACT: Concerns for the effects of global environmental change, caused primarily by the interrelated issues of environmental degradation and population growth, have prompted a consortium of international and national agencies to develop a "Framework for Evaluation of Sustainable Land Management" (FESLM). The FESLM, based on logical pathway analyses, provides a systematic procedure for identification and development of indicators and thresholds of sustainability. An assessment of sustainability is achieved by comparing the performance of a given land use with the objectives of the five pillars of sustainable land management: productivity, security, protection, viability, and acceptability. A classification for sustainability is proposed, and plans for future development of the FESLM are described.

KEY WORDS: Framework for Evaluation of Sustainable Land Management (FESLM), productivity, security, protection, viability, acceptability

Spaling, H. and Smit, B. 1995. "A Conceptual Model of Cumulative Environmental Effects of Agricultural Land Drainage." *Agriculture Ecosystems and Environment* 53: 99108.

ABSTRACT: Cumulative environmental effects are characterized by the temporal and spatial accumulation of change in environmental systems in an additive or interactive manner. Theoretical frameworks of cumulative environmental change generally follow a causal model consisting of the source of cumulative change, pathways of accumulation, and a typology of cumulative effects. These components, and the notion of temporal and spatial accumulation, are used to develop a conceptual model of the cumulative effects of agricultural land drainage in southern Ontario, Canada.

Drainage is a source of cumulative effects because of its temporally repetitive and spatially expansive nature. Drainage modifies flow regimes and contributes a mechanism for the spatial movement of water and contamination from one location to another. Potential cumulative effects of drainage include the repeated addition of drain water to receiving systems (time crowding), the systematic gathering of contaminants at higher concentrations relative to the source (spatial crowding), and their transport from agroecosystems to aquatic ecosystems downstream (cross-boundary movement), as well as the severing of natural areas resulting in altered landscape structures and functioning (spatial fragmentation). The model hypothesizes that as drainage density increases, change in environmental components or processes manifest themselves as cumulative effects, and that these effects accumulate at broader temporal and spatial scales.

NOTES:

Pillar: Protection
Indicator: Agricultural land drainage
Description: The collection, transport, and disposal of gravitational water from soil
Scope: Regional
Unit of measurement: A cumulative effects model
Methods of measurement: The cumulative nature of drainage is apparent in increasing drainage density over time.

Potential cumulative environmental effects of agricultural land drainage

Cumulative effect	*Environmental change*	*Description of cumulative effect*
Time crowding	Change in stream flow	Repeated addition of drain water at intervals which exceed the time required for assimilation or recovery to pre-drainage conditions
Space crowding	Nonpoint sources of contaminants	Incremental increases in spatial density and connectivity of drainage system within an area resulting in spatially diffuse sources of environmental change
Compounding	Change in aquatic organisms	Steady addition of sediment, nutrients, and pesticide residue collectively altering habitat and species composition
Time delay	Altered timing of drain flow	Prolonged drain discharge under saturated soil conditions, and lagged response under dry antecedent conditions
Cross-boundary flow or space	Movement of contaminants	Constant collection and transport of water and contamination from one location to another so that environmental change appears some distance away from the source
Triggers and thresholds	Lowering of water table	Continual removal of soil permanently alters the depth of the water table
Indirect effects	Decline in soil fertility due to change in land use	Gradual change in soil nutrient and organic matter content due to runoff, erosion, leaching, and so on associated with monoculture cropping patterns and management
Patchiness or fragmentation	Change in pattern of the rural landscape	Piecemeal fragmentation of ecological structure and functioning at the landscape scale

KEY WORDS: Protection, drainage

Steiner, K.G. 1996. "Causes of Soil Degradation and Development Approaches to Sustainable Soil Management." Richard Williams, trans. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH. Margraf Verlag, Weikersheim, Germany. 50 pp.

NOTES:

This report pinpoints the basic biophysical and socioeconomic causes of soil degradation and suggests approaches to remedying them. These approaches should be tailored to the special needs of land users in individual ecological regions. They should be closely geared to the specific situation, and the interventions must address different levels in both production technology and in the social sphere. This calls for new initiatives in development cooperation. The partner countries must be given more assistance in drafting soil policy and soil conservation strategies as well as in developing production techniques to conserve soil. Land users will only adopt new, sustainable cropping techniques if these result in economic gains. To ensure this, legal and economic parameters need to be reformed.

KEY WORDS: Soil management

Syers, J.K. Hamblin, A. and Pushparajah, E. 1995. "Indicators and Thresholds for the Evaluation of Sustainable Land Management." *Canadian Journal of Soil Science* 75: 4, 423-8.

ABSTRACT: Within the context of major land uses such as agriculture, the indicators of sustainability must be framed within the social and economic conditions of the society in question. Whereas an indicator is used to measure changes in key attributes, usually over time, a threshold provides a baseline against which sustainability can be assessed. A direct measure of sustainability using indicators is difficult, and indirect measures or surrogates may be easier to establish. There is some information on threshold values for indicators, particularly for indicators such as soil acidity and nutrient status and for those relating to root physiology. Because some threshold values are soil specific, it seems likely that a range of values will be required for a particular indicator. A few case studies involving indicators and thresholds for sustainable land management are available. Examples of soil and land suitability for the production of *Hevea brasiliensis* (rubber) in Malaysia and for the management of sloping lands for annual crops in the Philippines are discussed. Biophysical indicators and thresholds for sustainable rubber production appear to be reasonably well understood, particularly those relating to climate and soil physical factors. For sloping lands in the Philippines, yield data and benefit-cost ratios give a clear picture of trends and sustainability.

KEY WORDS: Indicators (general), sustainable land management, productivity, viability

U.K. Ministry of Agriculture Fisheries and Food. 1996. "United Kingdom Report on Agricultural Nutrient Management Indicators." COM/AGR/ENV/EPOC(96)86. Organisation for Economic Co-operation and Development, Paris. 14 pp.

NOTES:

Pillar: Acceptability
Indicator: Nutrient management

Based on an international seminar (Brighton, U.K. April 2930, 1996) the following are proposed as suitable for development as components of a comprehensive indicator of nutrient management.

Unit of measurement: Use of analysis for soil phosphorus

Methods of measurement: High soil phosphorus levels are associated with increased phosphorus loss to the environment. This indicator could be a measure of the proportion of agricultural land that is sampled regularly and analyzed for phosphorus, gathered by counting the number of soil samples taken. A better alternative is a survey to monitor trends in the soil phosphorus level of agricultural soils, as carried out in the U.K. and other countries. The use of different methods of soil analysis in OECD countries does not invalidate national comparisons of trends.

Unit of measurement: Presence of a nutrient management plan on the farm

Methods of measurement: The presence of a nutrient management plan on a farm is a positive sign that the farmer is taking steps to manage nutrient inputs efficiently. Some form of minimum standard on the components of such a plan would need to be employed. There could be difficulties in comparing those countries with legal requirements for plans and those adopting a voluntary approach.

Unit of measurement: Areas of agricultural land in government and other land management schemes that require less than normally recommended nutrient inputs

Methods of measurement: It was recognized that it was of value to know how much agricultural land was included in government schemes that require less than normally recommended amounts of nutrients to be applied. Data on this indicator would be available from government records.

Unit of measurement: Area of agricultural land receiving excessive (above recommended) nutrient inputs

Methods of measurement: Discussions have recognized the importance of excessive nutrient inputs on overall nutrient loss of both nitrogen and phosphorus, but have concluded that no practical means of assessing how much agricultural land treated in this way is available.

Unit of measurement: Timing of slurry application/months of available storage on the farm

Methods of measurement: Timing of application of animal manures containing a high proportion of their nitrogen in a form that is readily converted to nitrate (slurries and poultry manures) is recognized as crucial to how much nitrate is lost. The most direct, analytically sound approach is to monitor the timing of application of these manures. Discussions conclude that this is desirable but would require new data in most, if not all, OECD countries. Only those where application is banned for certain months have an indirect source of information.

Hence the most practical alternative is to assess the number of months of storage available on farms. Again, this information tends to be available in countries with regulatory requirements but not necessarily in other countries. In any case this includes slurries but not poultry manures.

Unit of measurement: Use of low ammonia emission slurry application machinery

Methods of measurement: The choice of slurry application technique to minimize ammonia loss is particular to those countries with regulations and targets to reduce ammonia emissions. Little data appears to be available (from public sources) in other OECD countries, but it might be possible to obtain such data from trade associations and individual countries.

It would seem sensible to have a common set of attributes of nutrient use, from which individual countries could choose according to their relevance. Authors consider the proposed indicators to be analytically sound in relating to nutrient loss, but recognize that none on its own is likely to be an adequate response indicator of a particular nutrient related environmental concern. The availability of current data is nil for many of these proposed indicators, especially in countries where there is no regulation of the particular activity. The appropriate level of aggregation of data has not been addressed.

KEY WORDS: Acceptability, nutrient management

UNEP. 1995. "Sustainable Development Indicators." *EarthNews*, Sec. Assessment and Reporting, January 1995, p. 1.

NOTES:

Indicators are tools used to communicate and make accessible statistical, scientific, and technical information to nontechnical user groups.

Descriptive indicators summarize sets of individual measurements pertaining to an issue; they are factual and derived objectively; they mainly serve scientific purposes.

Aggregated, policy-oriented indicators are derived from analysis and integration of information of different disciplines; they contribute to policy- and decisionmaking.

Currently, the Environmental Assessment Programme's (EAP) efforts are directed to:

Reviewing international work

Coordinating, with UNSTAT, information-sharing among organizations such as the UNDP, DPCSD, the World Bank, SCOPE, and WRI that are cooperating in this area

Harmonizing approaches

Aggregating with SCOPE, WRI, and others indicators for decisionmakers

Encouraging greater user involvement. EAP's strategy in the case of descriptive indicators includes:

Support for the development of descriptive indicators in a selected number of areas corresponding with major UNEP programs

Assistance to DPCSD in the development of international agreement on a basic set of indicators

Continued coordination, with UNSTAT, of the consultative group for informal collaboration in the field of indicators

Promotion of the use of indicators in SOE reporting and for the presentation of environmental data and information.

In the case of aggregated, policy-oriented indicators, the EAP's strategy includes:

Developing a selected number of aggregated indicators, consistent with Agenda 21, to support specified international policies, priority identification, and resource allocation

Continuing to support and guide the SCOPE/UNEP indicator project.

KEY WORDS: Indicators (general)

UNEP. 1997. *Global Environmental Outlook.* Nairobi, Kenya. 264 pp.

SUMMARY: The report shows that significant progress has been made over the last decade in confronting environmental challenges in developed and developing countries. Worldwide, the greatest progress has been made in institutional development, international cooperation, public participation, and the emergence of the private sector. International conventions on biodiversity, climate change, and desertification are in place, along with an increasing array of voluntary agreements, codes of conduct, and guidelines. However, the environment has continued to degrade during the decade, and significant environmental problems remain deeply imbedded in the socioeconomic fabric of nations in all regions.

In developing countries the primary emphasis is on limited availability of land for agricultural expansion, abatement of land degradation, efficient land and water management, land tenure, dryland degradation, and loss of land for urbanization. In industrialized countries the emphasis

is on soil pollution and control of acidification. The advance of the agricultural frontier and loss of biodiversity are major issues for forested areas. All regions are experiencing problems related to surface and groundwater quality, all major cities have air quality problems, about 30 percent of the world's coastal systems are at high risk of degradation, and even the polar regions are experiencing long-range pollutant transport and deposition problems.

The report uses a wide variety of indicators to report on the status and rate of change (trends) in regional and global environments. Indicators are reported for major geographic areas, the important underlying causes, and by sector. Indicators are subdivided into social, economic, institutional, and environmental causes.

NOTES:

Pillars: Varied
Indicators: Varied, environmental, sector, institutional
Scope: Global, national, regional
Unit of measurement: Varied

KEY WORDS: State of environment, global, degradation, GIS, agriculture, forestry, water, biodiversity, desertification

UNEP and UNDP. 1994. *International Symposium on Core Data Needs for Environmental Assessment and Sustainable Development Strategies.* Bangkok, Thailand, 1518 November 1994. Vol. 2. 130 pp.

NOTES:

The United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) organized this international symposium to:

- Seek consensus on priority environmental assessment and sustainable development issues and the core datasets needed to respond to these issues
- Define the minimum characteristics of these data in relation to national and transnational purposes
- Establish collaborative mechanisms to foster the harmonization of core environmental data
- Examine the barriers to general access and use of these data.

For the purpose of this symposium a core dataset is defined as a consistent set of basic data that can be used in the analysis of a variety of environmental assessment and sustainable development issues.
Following keynote and background presentations, participants reviewed the successes achieved and challenges faced in three international case studies:

- The Pan-Amazonia Project
- The Zambezi Project
- The Mekong Project.

A variety of UNEP programs were also reviewed.

Conclusions

Ten high-priority core datasets central to many types of studies that produce environmental assessment information and sustainable development strategies were identified:

- Land use/land cover
- Demographics
- Hydrology
- Infrastructure
- Climatology
- Topography

Economy
Soils
Air quality
Water quality.

Having identified these priority core datasets, participants then agreed that methods must be established to develop, maintain, and make openly accessible core data.

KEY WORDS: Indicators (general)

Van Woerden, J.W. Diederiks, J. and Klein Goldewijk, K. 1995. *Data Management in Support of Integrated Environmental Assessment and Modelling at RIVM.* Report 402001006. National Institute of Public Health and the Environment (RIVM), Bilthoven, The Netherlands. 215 pp.

ABSTRACT: This report describes how global and regional datasets are managed within RIVM in relation to UNEP's Global Environmental Outlook and other environmental assessments and global change studies.

The majority of these datasets serve as core input data for assessments and modeling activities, while a smaller number of datasets reflects the result of these activities. Moreover, such core data typically form the basis for defining and deriving environmental indicators for integrated environmental assessment.

Logistically, these "international" datasets are integrated into the overall information infrastructure currently under construction within RIVM, including systems for managing datasets, metadata (information about the data), quality control, data visualisation, and report presentation.

In addition to providing a selection of metadata such as the 1995 Catalogue of International Datasets, an attempt has been made to put the logistical work on data into a wider context for environmental data management. This is done by describing both how data needs have been made explicit and how the information infrastrucure has been developed and applied to date.

KEY WORDS: Indicators (general), data source

Wachter, D. 1996. "Land Tenure and Sustainable Management of Agricultural Soils." Development and Environment Report 15. Centre for Development and Environment, University of Berne, Berne, Switzerland. 39 pp.

NOTES:

Pillar: Acceptability
Indicator: Land tenure
1. Land tenure insecurity
2. Inequality of land ownership
Description:
1. Land tenure insecurity looks at the influence of tenure insecurity on incentives to use land in a sustainable manner or willingness to invest in sustainable practices.
2. Inequality of land ownership may be a problem in that the land market fails to operate efficiently and leads to inefficient use or misuse of land resources. For example, large landowners often value their holdings for the power and prestige they confer rather than for their agricultural potential.
Scope: Local, regional, national

Conclusion: The report concludes that the relationship between land tenure and land degradation is complex. There are no unambiguous, easy solutions applicable throughout the developing world. The basic fact that individual land users need secure tenure in order to be in a position to develop long-term sustainable land-use strategies does not yet lend itself to specific policy interventions, since what constitutes tenure security differs widely all over the developing world.

At the same time land tenure clearly is a crucial factor influencing the behavior of farmers. It is suggested in this study that providing appropriate land-tenure arrangements is a necessary, but not sufficient, condition for sustainable use of agricultural soils. Other provisions, such as agricultural extension, attractive product prices, and so forth are also needed.

KEY WORDS: Acceptability, land tenure

Wallis, N.J.A. 1997. *Intensified Systems of Farming in the Tropics and Subtropics.* World Bank, Washington, D.C. 213 pp.

ABSTRACT: A review of eight intensified systems of land use on unirrigated farms in developing countries is used to propose three complementary sets of conditions necessary for farming systems to be sustainable in the long run. These three sets of conditions, or "domains," are public sector policies and investments; private farmers, their families, and institutions; and scientific principles, natural resource endowments, and ecological systems.

The eight farming systems represent a wide range of geographic and resource features and contrasting sociological conditions in Africa; south, east, and west Asia; and Latin America. They include the reduction of the proportion of fallow land in Turkey, dairy development in Uruguay, associated cropping on small farms in Columbia and Nigeria, the opening up of the *Cerrados* region of Brazil and the development of minimum tillage and direct drilling practices on largescale soybean farms, soybean growing by small-scale farmers on black cotton soils in central India, and two examples of perennial crop development on estates and smallholdings in Kenya (tea) and Malaysia (oil palm).

In all cases the role and policies of governments have been of crucial importance, particularly in the following respects:

- Creating transport infrastructure, such as railway and road systems
- Facilitating and promoting active markets for farm products and, for some seasonal crops, establishing floor prices
- Minimizing direct involvement in product marketing
- Maintaining realistic foreign exchange rates.

Farmers have responded rapidly to market opportunities when they have been confident that they could sell all their product surplus to family requirements. Price predictability appears to have been more important than the level of farm gate prices. Falling prices have generally induced intensification of production. Social customs affect considerably the sequence and degree of change in farming practices. Centrally organized group farming among small-scale oil palm growers in Malaysia has been successful, but in other cases the intensification of farming systems has been the result of many separate decisions by individual farmers. Major improvements in resource use have occurred, but in the cases of India, Nigeria, and Turkey communal decisions and actions on landscape planning will be necessary to sustain the changes already made.

All the cases show the importance of scientific research, but with the exception of tea in Kenya and oil palms in Malaysia, research efforts have been sporadic, are seldom well-balanced, and usually are not documented in the international scientific press. Plant breeding and selection has often been successful but poorly supported by studies of soil and water management and hydrol-

ogy. Soil studies have generally been weak regarding soil organic matter and biological activity in the rooting zone of crops and pasture plants. All the cases illustrate the importance of leguminous species in the farming system, but in general these species have not been adequately studied. Much research has been weak on socioeconomic variables, and consequently the results and possibilities for improved use of natural resources have been poorly understood by policymakers.

KEY WORDS: Viability, acceptability, resource management

Warren, D.M. 1992. "A Preliminary Analysis of Indigenous Soil Classification and Management Systems in Four Ecozones of Nigeria." Discussion Paper RCMD 92/1. International Institute of Tropical Agriculture, Ibadan, Nigeria. 28 pp.

ABSTRACT: (Conclusion) The three indigenous soil classification systems for the Yoruba, Kulere, and Hausa are very similar, being based on identifiable properties of texture, color, and water retentiveness. All three systems include comparable knowledge of the nature of soil fertility and ways to retain and improve fertility. All systems have knowledge of soil erosion and management systems designed to curtail it. It is also clear that we can learn a great deal from small-scale farmers, even through this type of rapid rural appraisal approach to the recording of indigenous knowledge systems. Farmers in all three sites have limited access to inorganic fertilizer. The traditional types are considered better for long-term sustainability of the soil structure and fertility.

KEY WORDS: Indigenous knowledge

Warren, D.M. 1994. "Indigenous Agricultural Knowledge, Technology, and Social Change." In *Sustainable Agriculture in Eastern North America*, McIsaac, G. Edwards, W. and Riley, T., eds. University of Illinois Press, Urbana.

ABSTRACT: Pre-and post-contact Native Americans, early Finnish settlers, the Amish of Iowa, conventional capital-intensive agriculturalists, and the Practical Farmers of Iowa can provide us with insights into the nature of sustainable agriculture in the eastern United States. Native American agriculture, as reflected in extensive approaches to farming, met the environmental, social, and economic criteria of sustainability but could not be sustained after the impact of European contact. The preadapted knowledge system of the Finnish immigrants gave them a basis for successful opening of the frontier, but its extensive approach made it unsustainable when all arable land fell under intensive approaches to agriculture. Amish agriculture in Iowa has been highly sustainable, weathering a variety of adverse situations over more than a century-and-a-half of intensive farming. The mainstream farming since World War II has recently been questioned. As the reliable supply of low-cost fossil fuels declines, alternative approaches to agriculture are being attempted as reflected in the experiments of the Practical Farmers of Iowa. An understanding of the characteristics that made precontact Native American agriculture sustainable and make contemporary Amish farming sustainable can help us determine the directions that mainstream agriculture may take in the future.

NOTES:

By recording indigenous knowledge it is possible to compare and contrast it with scientific knowledge available through the international network of universities and agricultural research insti-

tutes. Aspects of indigenous knowledge that are beneficial, as well as those that could be improved through technologies available through the international scientific knowledge system, can be identified. Development professionals are increasingly recognizing the value of this type of knowledge in helping them work more effectively with local communities to solve their agricultural and environmental problems in participatory approaches.

KEY WORDS: Indigenous knowledge

Warren, D.M. 1995. "Indigenous Knowledge for Agricultural Development." In "Workshop on Traditional and Modern Approaches to Natural Resource Management in Latin America," 2526 April 1995. World Bank, Washington, D.C.

NOTES:

Keynote speech provides a brief chronology of the growing interest in indigenous knowledge in agriculture development and proceeds to describe work being done by the global network of indigenous knowledge resource centers.

KEY WORDS: Indigenous knowledge

Weber, F.R. 1991. "NRM Indicator Catalogue." World Resources Institute, Washington, D.C. 28 pp.

NOTES:

This draft catalogue prepared for the U.S. Agency for International Development identifies many of the same indicators identified elsewhere, but does not provide quantitative measurement data.

The indicators covered are:

- Productivity
  - Goods produced
  - Agricultural yields
- Water quality
  - Physical, chemical, and biological properties
- Land use
  - Ratios of farmland, permanent pasture, forest and shrub land, other land
  - Percentage change since last ratios were determined
- Land classification
  - Actual versus safe land use by standard classification
  - Adequacy of fallow length
- Soil fertility
  - Chemical and physical soil properties
  - Wind and water erosion
  - Soil moisture retention
- Biodiversity
  - Inventory of sites
  - Designated of actually protected vs. total area or sites
- Land management practices
  - Number of people/families experimenting with new practices
  - Percentage of people (out of total population) adopting new practices
- Economic considerations
  - Extent of and conditions under which financial materials or other incentives are available

Fees, permits, taxes on owning, harvesting, storing, selling, or trading farm livestock, tree, and forestry/bush assets or products and the disincentive they may represent

Costs and availability of inputs.

KEY WORDS: Indicators (general)

Winograd, M. 1995. "Environmental Indicators for Latin America and the Caribbean: Toward Land-Use Sustainability." Ecological Systems Analysis Group, CIAT, Cali, Colombia. 83 pp.

NOTES:

Environmental indicators are needed to analyze and monitor development processes. However, development policies and strategies are elaborated and applied at different levels of society, and the effects and consequences of such policies are observed at different scales. Indicators must, therefore, be selected in relation to these characteristics and to the users' needs.

The goal of this work is to prepare a set of indicators that might be utilized in the evaluation and design of environmental policies. Part of the report puts indicators in the Pressure-State-Response framework. Of more interest is a fourth group entitled "Progress Toward Sustainability."

Anticipating the unsustainable aspects of development, as well as opportunities for and obstacles to the sustainable management of land and natural resources, is essential to the elaboration and application of sustainable development policies at the national and life-zone level in Latin America and the Caribbean. In particular it is necessary to question the ecological and technological feasibility of sustainable development at the regional level should profound political, social, and economic changes be implemented. For this purpose the most important information is that on productive potential, the amount of land needed to satisfy the population's basic needs, and the region's production goals. Using alternative scenarios to anticipate the environmental situation and the state of natural resources in the region is also essential in orienting development. Finally, information on the costs and benefits of sustainable models is needed so analysts can determine economic possibilities and financial needs.

Analysis based on these types of information will allow policymakers to elaborate specific responses at the regional level, strengthen local actions, and figure out how the region might contribute to the solution of global problems while satisfying its own basic needs. To help achieve this goal, indicators should show the local and regional results of applying various management approaches and selecting various land uses.

Land Use Indicators

Pillar: Protection
Indicator/Unit of measurement:
Forested area / million hectares
Annual deforestation / million hectares
Deforestation rate / annual percentage
Annual reforestation / million hectares
Reforestation-deforestation / ratio
Cropland area / million hectares
Pasture area / million hectares
Altered area / million hectares
Cropland per capita
Forested per capita
Net additions to the CO_2 flux for land-use change / millions of T of carbon

Net greenhouse gas emissions for land-use change / millions of T of CO2 equiv. carbon

Greenhouse gas emissions for land-use per capita / T of CO2 equiv. carbon

KEY WORDS: Emissions, forestry, indicators (general), sustainable land management, protection

World Bank. 1995. *African Development Indicators: 199495.* World Bank, Washington, D.C. 418 pp.

NOTES:

The task of monitoring Africa's development progress and aid flows requires basic empirical data that can be readily used by analysts. This publication, the third in a series, is meant to provide a starting point to fulfil that task.

This volume presents the available relevant data for 197493, grouped into 15 chapters: background data, national accounts, prices and exchange rates, money and banking, external sector, external debt and related flows, government finance, agriculture, industry, labor force and employment, public enterprises, aid flows, social indicators, environmental indicators, and household welfare indicators.

Each chapter begins with a brief introduction on the nature of the data, followed by a set of charts, statistical tables, and technical notes. The notes define the indicators and identify specific sources.

KEY WORDS: Indicators (general), data source

World Bank. 1996a. "Environmental Performance Indicators: A First Edition Note." Environment Department, World Bank, Washington, D.C. 24 pp.

SUMMARY: Choosing appropriate Environmental Performance Indicators (EPIs) to assess and evaluate the performance of World Bank projects in relation to environmental issues is a challenging task. The problems concerned are too complex for a small set of "universal" indicators to be developed. The stated objective of the project is to identify the most important source for the selection of appropriate EPIs for projects with explicit environmental objectives. The EA process serves as a guide to selection of EPIs in cases in which environmental impacts are unintended or indirect. Once the areas to be monitored have been identified in this way, specific indicators can be selected to monitor how the project is affecting the pressures on the environment and the end result of these pressures. In some cases these might be similar to indicators used as national-level indicators, but perhaps collected at a different spatial scale; in others, quite different indicators might be most appropriate. Where possible, it is desirable to select indicators that will be comparable to broader measures of environmental health or be comparable across projects, but this may not always be feasible.

KEY WORDS: Indicators (general)

World Bank. 1996b. "Towards Environmentally Sustainable Development in West Central Africa." West Central Africa Department, World Bank, Washington, D.C.

NOTES:

The objective of this paper is to provide a basis for discussing sustainable development in West Central Africa. In the past, calculations of the benefits from development have rarely included costs to the environment. Population growth and agricultural expansion have contributed

substantially, for example, to the loss of most of West Central Africa's high forests, which raises serious questions about the long-term benefits of traditional growth policies. The challenge today is to ensure that future development is sustainable, meaning environmentally responsible. This paper discusses how the Bank can help mainstream environmental sustainability in the development programs of the seven countries of West Central Africa.

The enormous array of issues underlying sustainable development emphasizes the urgent need to set priorities and develop realistic action programs within the constraints imposed by the limited availability of human and financial resources. Some priorities are suggested in the following discussion, but action programs will, of course, be further defined as governments develop their country strategies, including their policies and investment programs.

KEY WORDS: Indicators (general)

WRI. 1992. "Environmental Indicator Work at the World Resources Institute." World Resources Institute, Washington, D.C. 9 pp.

NOTES:

Prepared for the World Resources Institute Workshop on Global Environmental Indicators (December 78, 1992). Provides a brief overview of WRI's work including:

Indices
- Greenhouse gas index
- Green cities index
- Natural endowment index
- Metal reserves index
- Species area "index"

Indicator papers and studies
- "Developing Indicators of Biodiversity Conservation"
- "The Growing Importance of Scientific Rules of Thumb in Developing Indicators of Resource Sustainability"
- "Developing Urban Environmental Indicators in Third World Cities"
- "Environmental Trends in Latin America: Progress toward Land Use Sustainability"

Natural Resource Accounting.

KEY WORDS: Indicators (general)

Zinck, J.A. and Farshad, A. 1995. "Issues of Sustainability and Sustainable Land Management." *Canadian Journal of Soil Science* 75: 4, 407-12.

ABSTRACT: The concept of sustainability has many facets. Ecologists, environmentalists, agronomists, sociologists, economists, and politicians use it with different connotations. In addition, the sustainability of land management systems varies in space according to climate, soil, technology, and societal conditions. Sustainable farming systems vary also in time, as they evolve and may collapse, frequently together with the corresponding sociosystems. Because of its complexity, sustainability is difficult to measure directly and requires the use of appropriate indicators for assessment. A good indicator is free of bias, sensitive to temporal changes and spatial variability, predictive, and referenced to threshold values. Relevant data are often incomplete or inadequate for indicator implementation. To embrace the whole breadth of sustainability, several methods and techniques should be used concurrently, including land evaluation and coevolutionary, retrospective, and knowledge-based approaches. It is, however, at the application level that major

constraints arise. A sustainable land management system must satisfy a large variety of requirements, including technological feasibility, economic viability, political desirability, administrative manageability, social acceptability, and environmental soundness. Real world conditions at the farm and policymaking levels need to be substantially improved to achieve land management.

KEY WORDS: Sustainable land management

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Catalogue of URL Sites for Indicators of Land Quality and Sustainable Land Management

There has been a virtual explosion in the amount of information available on the Internet. Two major problems continue to plague researchers using this technology as an aid. First, there continues to be a problem finding relevant information. Using the various search engines, a search for "land quality indicators" or "sustainable land management" could yield almost one million "hits," some of which are relevant, but many more of which are not. A second major problem is that the technology is in its infancy, and those using it are still grappling with what type of information and how much of it to post on the Internet. As a result many sites contain only general information about organizations and projects, products, and services. Attempting to get significant detail has proven to be a challenge. Fortunately, some organizations have taken the initiative and are creating WWW catalogues that provide links to agricultural and agri-environmental sites. Some of the better ones are listed below.

A. Launching Points

World Wide Web Virtual Library: Agriculture

URL: http://ipmwww.ncsu.edu/cernag/cern.html

*Compiler:*NSF Center for Integrated Pest Management, at North Carolina State University

Content: Provides links to agriculture sites around the world; agriculture-related newsletters, periodicals and electronic textbooks; databases and software; WWW virtual library sites relevant to agriculture (broken down by subject); resources containing lists of WWW sites relevant to agriculture;and horticulture information

Accessibility: While this site has no restrictions on access, some of the sites it links to may have restrictions

Virtual Library on International Development

URL: http: //w3.acdi-cida.gc.ca/ virtual.nsf/pages/index_e.htm

Compiler: International Development Information Centre (IDIC) of the Canadian International Development Agency (CIDA)

Content: A collection of links to international development resources on the Internet, broken down by organizations, thematic resources, regions and countries. Thematic Resources: Agriculture provides links to over 20 sites with references to agriculture and international development.

Accessibility: No restrictions

Consultative Group on International Agricultural Research (CGIAR)

URL: http://www.worldbank.org/html/cgiar/homepage.htm

Compiler: World Bank

Content: Describes activities of the Consultative Group on International Agricultural Research (CGIAR)

and provides links to research centers

Accessibility: No restrictions

Comment: This site and those of the research centers tend to be very general, with the exception of the Center for International Forestry Research (see Land Quality and Sustainable Management Indicator Sites).

AgDB: The Agriculture-Related Information Systems, Databases, and Datasets AgNIC Prototype

URL: http://www.agnic.org/agdb/

*Compiler:*National Agricultural Library's (NAL) Electronic Research Database Committee (ERDC)

*Content:*Identifies and describes agriculture-related databases, datasets, and information systems. Not all datasets described are available on the Internet, but for those that are, links have been established to the actual data wherever possible.

Accessibility: All the AgDB metadata records may be viewed through the alphabetical list, arranged by resource name. The full text of all metadata records is searchable through a keyword index. As part of this function one can search by AGRICOLA Subject Category Code, permitting the user to apply a broad level, human-indexed screening to a rough keyword search.

U.N. System Wide EARTHWATCH Site

URL: http://www.unep.ch/earthw.html

Compiler: UNEP

Content: The site has been completely revised and expanded. It includes:

Short summaries of emerging environmental problems, referenced to the

scientific literature

Listing of the major recent environmental assessments

Updates on the organization of Earthwatch

Documents on Earthwatch, including Earthwatch Working Party reports

Revised pages on the environmental information activities of relevant U.N. organizations, linked to their WWW site. Special topics, such as indicators, global international waters assessment.

Accessibility: No restrictions

B. Land Quality and Sustainable Land Management Indicators Sites

Agricultural IndicatorsIndicator Program Descriptions

*URL:*http://tdg.uoguelph.ca/www/FSR/collection/indicator/program.txt

Compiler: S. McCann, World Resources Institute

Content: Profiles of 37 programs currently involved in developing indicators of agricultural sustainability. The profiles are arranged in four categories based on the focus of the organization's indicator output or reports. The categories include the global and national level; the regional level (ecoregion, watershed, landscape); the community, project and farm level; and the soil level.

Accessibility: No restrictions

Review and Assessment of Available Indicators for Evaluating Sustainable Land Management

URL: http://res.agr.ca/PUB/ecorc/program3/pub/indicat/overview.htm

Compiler: Centre for Land and Biological Resources Research, Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada

Content: Report investigates some potential indicators for assessing the sustainability of agricultural land management in Canada. The focus is on the sustainability of agricultural resources. Data from the 1991 Census of Agriculture were used, where possible, to determine indicators, because the data are current and equally representative of all parts of the country.

- Framework for Assessment of Sustainable Land Management
- Variables, indicators, and thresholds
- Criteria for choosing indicators
- Review of available indicators
  - Physical
  - Agronomic
  - Economic
  - Social
- Assessment of selected indicators
  - Physical
  - Agronomic
  - Economic
  - Social
- Conclusions
- Appendix I: Alternative Approaches to the Development of Indicators
- Appendix II: Indicators of Soil and Water Quality
- References

Accessibility: No restrictions

Comment: This is an electronic version of the Neave and others (1995) report.

Center for International Forestry Research (CIFOR)

URL: http://www.cgiar.org/cifor/

Compiler: CIFOR

Content: Includes general information, maps, and statistics on at least 80 countries from WCMC, one of CIFOR's collaborators, as well as summaries of its research projects, including its criteria and indicators project.

Accessibility: No restrictions

Compendium of Sustainable Development Indicator Initiatives and Publications

URL: http://iisdl.iisd.ca/measure/compendium.htm

Compiler: International Institute for Sustainable Development, Environment Canada, Redefining Progress, and the World Bank.

Content: Provides an overview of initiatives on Sustainable development indicators being carried out at the international, national and provincial/territorial/state levels.

Accessibility: No restrictions

Consortium for International Earth Science Information Network (CIESIN)

URL: http://www.ciesin.org/

Compiler: Consortium for International Earth Science Information Network

Content: Provides interactive applications, metadata resources, data resources, information systems and resources. Although much of the information is U.S.-based, the Land and Water Knowledge Management Node (LW-KMN) (http://www.ciesin.org/lgi-is/lw-kms) is a global information sys-

tem being developed by CIESIN and supported by the World Bank, the Consultative Group on International Agricultural Research (CGIAR), the Food and Agriculture Organization (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP). The information system provides searchable metadata and tools for access to source data and indicators.

Interactive Applications

DDCarto Demographic Data Cartogram Service: Interactive order of 1990 US census data in prominent GIS data formats

DDViewer Demographic Data Viewer: Interactive mapping of 1990 U.S. census data

ENTRI Environmental Treaties and Resource Indicators Service: A searchable relational database containing international environmental treaties, treaty summaries, treaty status files and natural resource indicators

Geocorr Geographic Correspondence Engine: Create correlation lists between various U.S. geographies

Great Lakes Map Server: Interactively compose a map with selected EPA site datasets and feature coverages for any U.S. region within the Great Lakes

MVA Model Visualization and Analysis for Integrated Assessment Models of Climate Change: Access to guide information on Integrated Assessment Modeling, selected lAMs, and scenario outputs from selected lAMs

Ulysses (tm) Cross-Tabulation Engine: Interactive access to decennial U.S. census microdata

UVIS UV Interactive Service: An interactive, custom-query service that allows for on-screen visualization of hourly, daily, and monthly UV dose variables from selected locations across the United States

AgCrOPS Agricultural Crops Observation and Performance Service (Experimental Prototype*):* A farmers' quick reference guide to the results of crop varietal trials and a one-stop seed products catalogue

Metadata Resources

ClESIN's Guide to Metadata: Information and resources about metadata

CIESIN Gateway: Locate environmental and socioeconomic data using this distributed international catalog of metadata resources

GLREIS Metadata Search: Search the Great Lakes Regional Environmental Information System Metadata Directory

CIESIN Dataset Guides

Data Resources

Archive of Census Related Products: Post-processed extracts from the 1990 STF3A and 1992 TIGER data linked by polygon ID number; U.S. population, housing density and land cover classification data on a 1km2 grid

China Dimensions Data Collection: Guides for and access to a rich collection of data resources on the People's Republic of China. Highlights include digital administrative boundaries; fundamental GIS layers; county-level data on population, agriculture, economics, and hospitals; and interactive acess to he 1982 census of population

Environmental Treaty Texts: Full text of more than 140 international environmental agreements

Gridded Population of the World: Dataset description and access to world and continental population counts and density on a 5 minute grid

Global Population Database: Population data on a 20 minute by 30 minute grid for more than 100 nations; includes urban density circles

Mexico Data Collection: Dataset description and access to various population GIS coverages of Mexico

Monitoring Environmental Progress: Interactive query of the World Bank's database of indicators of environmentally sustainable development

Public Use Microdata Samples (PUMS): Microdata from the decennial U.S. censuses of 19701990

Social Indicators of Development: Interactive query of the World Bank's dataset containing 125 socioeconomic variables from more than 170 economies for the period 19651993

World Resources 199697: Interactive query of the authoritative Guide to the Global Environment from World Resources Institute

Information Systems and Resources

Access to U.S. Demographic Data: A collection of applications and data resources for analysis of U.S. demographics

Great Lakes Regional Environmental Information System (GLREIS): GLREIS provides access to a wide array of data, information, and unique tools relevant to the Great Lakes region

Land Quality Indicators Information System: LQI-IS is a global information system on the sustainability of land resources in managed ecosystems (http://www.ciesin.org/lqi-is/Iqihome.html) containing the following entries:

What is LQI-IS? Background on the Land Quality Indicators Information System

Search for Metadata: Allows the search and retrieval of descriptions of LQI data and information

Accessible Datasets: Access to LQI-related datasets

Indicator Guides: Descriptions of LQIs and links to related data sets

Modeling: Access to LQI-related modeling tools

Discussion Forum: Access to an on-line discussion area

Tools and Software: Access to other LQI tools and software products

Bibliographies: Access to LQI bibliographies

Related Web Sites: Access to other Web sites

U.S.-Mexico Border Regional Environmental Information System (US-MBREIS): US-MBREIS provides access to data, information and unique tools relevant to the United States-Mexico Border region

Stratospheric Ozone and Human Health Project: A suite of information products in the areas of ultraviolet (UV) radiation, ozone, and human health impacts of UV exposure

Thematic Guides to key environmental issues, including: agriculture, human health, land use, ozone depletion, political institutions, remote sensing, environmental treaties, resource indicators (designed to support the ENTRI service), and integrated assessment modeling of climate change (designed to support the MVA service)

Accessibility: No restrictions

Global Resource Information Database (GRID)

URL: http://www.grida.no/prog/global/cgiar/index.htm *Compiler:* A joint project of the United Nations Environment Programme, Global Resource Information Database (UNEP/GRID) and the Consultative Group on International Agricultural Research (CGIAR). The main objective of the UNEP/CGIAR project for the "Use of Geographic Information Systems in Agricultural Research Management" is to establish long-term cooperative links between UNEP and the CGIAR system to effectively integrate natural resource and socioeconomic information into agricultural research activities

Content: Provides an overview of the project and newsletters and reports back to 1995, as well as datasets and links to other CGIAR sites.

Datasets

Asian population databases

Latin American administrative boundaries

Data Catalogue: Compiled to help members of the CGIAR network to find data available at the other Centers or to have an overview of all self-produced data existing in the CG Centers. The catalogue contains search information, such as geographical coverage, date of collection, (INFOTERRA) keywords for orientation, contact persons for requests, source information and so on, and is designed to be combined with the UNEP/GRID metadatabase

in the near future. Most of the datasets are in vector format, including the administrative boundaries and communication infrastructure for countries of South America, The Philippines and Central Africa. Some general elevation and land use data in roster format is also available, mostly for Africa (Côte d'lvoire) and the Philippines. Climatic data is maintained for almost every region of focus, but complete time series are missing. Datasets are relevant for agricultural activities in those regions, supporting the modeling and research of related issues, mainly concerning potato and rice production. Almost every dataset is stored in Arc/Info format; some of them are also in IDRISI. The catalogue can be obtained as an Excel (5.0) .xls file by ftp from the site, GRID/Arendal, or you can download separate Excel or Word files for one or more of the Centers

Accessibility: No restrictions

Comment: Geographic analysis can provide a considerable input to agricultural research where the spatial dimension is relevant. Applications range from service functions, such as collecting and providing geo-referenced data, to modeling of crop yields, identification of key areas of population pressure, biodiversity conservation, and complicated impact assessment analyses. The importance of GIS in agricultural research is increasing as environmental management gains a regular place on agricultural research agendas.

International Development Research Centre (IDRC)

URL: http://www.idrc.ca

Compiler: IDRC

Content: The International Development Research Centre is a public corporation created by the Canadian government to help communities in the developing world find solutions to social, economic, and environmental problems through research. The site provides access to information about IDRC, including the Centre's general information brochure, annual report, news, media information, and the Centre's program of research. "Research Projects" offers direct access to international research sites including research initiatives and international secretariats. "Resources" links to the Centre Library, databases, catalogue of publications, and IDRC's archives. The IDRC Library provides public access to development information via the Development Data Bases Service (DDBS) at http:// www.ddbs.idrc.ca. DDBS databases:

BIBLIO The collection of the IDRC Library

IDRIS Inter-Agency Development Research Information System Research activities and projects of:

IDRC (International Development Research Centre)

IFS (International Foundation for Science)

JICA (Japan International Cooperation Agency)

Sida Department for Research Cooperation (SAREC).

Accessibility: No restrictions

Land and Water Knowledge Management Node

URL: http://ciesin.org/lw-kms

Compiler: World Bank

Content: The Land and Water Knowledge Management Node involves the development of:

A metadata base and access to Global Environmental Data, Institutional and Special Purpose Information Catalogues, and Modeling (links to Consortium for International Earth Science Information Network at http://www.ciesin.org/lw-kms)

An Inventory of LQI-Related Projects (for details, a request must be sent to the LQI Secretariat, Rural Development Anchor, World Bank)

A List of Publications.

Accessibility: No restrictions

Comment: The program and the global coalition being assembled to develop and disseminate information on land and water quality are important contributions toward more sustainable management

of the world's land, water, and biological resources. The objective is not a new program separate from the ongoing efforts of many agencies, but rather better coordination of the many existing and new initiatives on land resource management. This requires that the work be done in a coordinated, cooperative fashion, using a common framework.

The UNEP Meta-data Directory

URL: http://www.grid.unep.no/

Compiler: United Nations Environment Programme

Content: For the UNEP Meta-data Directory, the term "meta-data" is defined as reference data about the content and location of (environmental) data and information holdings. Meta-data are the high-level "overview" or informational abstract that describes (and points to) a particular dataset, report, map, or institute. Meta-data assist users by providing access to institutes and data.

The UNEP Meta-data Directory will serve as a library card catalogue of environmental information. It will contain "card entries" (or meta-data descriptions) of institutes and datasets. Similar to the library card catalogue, the meta-data directory will allow users to search for environmental information by institute name or dataset (title), contact person (author), theme, keyword, and location (subject), as well as other criteria.

Sample queries to this system may be: How many institutes are working on biodiversity in Europe and how can I contact them? Where are datasets available about vegetation in Kenya and how can I get them?

Accessibility: Since the goal of this software is to provide information free of charge to as large a global audience as possible, the audience for this directory is primarily (but not limited to) the environmental information-seeker who does not have network (Internet) access. Data in the directory can be interchanged freely among users and can be uploaded to the World Wide Web for users with Internet connectivity.

It will be necessary for all users of the MdD to register with GRID to ensure uniqueness of data entries. A security system is invoked at the beginning of each new participant's meta-data session. This verification process asks new users to identify themselves, the machine they are working on, and the organization they work for.

To sample the Meta-data Directory (demo version), contact James McKenna at UNEP: Tel:254.2.623899 or Fax: 254.2.624315 or e-mail: mckennaj@unep.org. UNEP is promoting its use and always looking for more partners with whom to share environmental information.

Sustainable Development Indicators, selected bibliography

URL: http://iisdl.iisd.ca/ic/info/ss9504.htm

Compiler: International Institute for Sustainable Development

Content: A listing of publications related to Sustainable development indictors. Brief descriptions are provided in some cases; however, there are no links to the publications themselves.

Accessibility: No restrictions.

SPAAR Information System (SIS)

URL: http://www.bib.wau.nl/sis/

Compiler: International Agricultural Centre (IAC), The Netherlands

Content: The Special Programme for African Agricultural Research (SPAAR) emerged as an initiative in tile mid-1980s to enhance agricultural production in Africa by increasing donor coordination in the field of agricultural research. The SPAAR Information System (SIS) was developed as a tool to come to grips with the increasing number of activities. It complements the registration of nationally funded projects in the CARIS database managed by FAO. It can search listing by keywords or by list of available research disciplines:

General Agriculture

Agriculture General Aspects (18 records)

Agricultural Research (358 records)

Geography and History

Geography (4 records)

History (3 records)

Education, Extension, and Information

Education (57 records)

Extension (15 records)

Documentation and Information (74 records)

Administration and Legislation

Public Administration (3 records)

Legislation (1 record)

Economics and Policies

Agricultural Economics and Policies (66 records)

Land Economics and Policies (42 records)

Labour and Employment (15 records)

Investment, Finance and Credit (16 records)

Development Economics and Policies (76 records)

Production Economics (18 records)

Organization, Administration and Management of Agricultural Enterprises or Farms (12 records)

Agro-industry (7 records)

Cooperatives (7 records)

Rural Sociology (38 records)

Rural Population (11 records)

Trade, Marketing and Distribution (40 records)

International Trade (6 records)

Domestic Trade (2 records)

Consumer Economics (2 records)

Home Economics and Crafts (1 record)

Agrarian Systems (7 records)

Plant Production

Crop Husbandry (206 records)

Plant Propagation (14 records)

Seed Production (33 records)

Fertilizing (40 records)

Irrigation (61 records)

Soil Cultivation (21 records)

Cropping Patterns and Systems (189 records)

Plant Genetics and Breeding (251 records)

Plant Ecology (11 records)

Plant Structure (5 records)

Plant Physiology and Biochemistry (35 records)

Plant Physiology Nutrition (13 records)

Plant Physiology Growth and Development (5 records)

Plant Physiology Reproduction (1 record)

Plant Taxonomy and Geography (9 records)

Plant Protection

Protection of Plants General Aspects (55-records)

Pests of Plants (382 records)

Plant Diseases (61 records)

Miscellaneous Plant Disorders (6 records)

Weeds and Weed Control (24 records)

Postharvest Technology

Handling, Transport, Storage and Protection of Agricultural Products (6 records)

Handling, Transport, Storage and Protection of Plant Products (58 records)

Handling, Transport, Storage and Protection of Forest Products (1 records)

Handling, Transport, Storage and Protection of Animal Products (3 records)

Handling, Transport, Storage and Protection of Fisheries and Aquacultural Products (9 records)

Handling, Transport, Storage and Protection of Non-food or Non-feed Agricultural Products (1 record)

Forestry

Forestry General Aspects (77 records)

Forestry Production (164 records)

Forest Engineering (4 records)

Processing of Forest Products (18 records)

Forest Injuries and Protection (2 records)

Animal Production

Animal Husbandry (142 records)

Animal Feeding (40 records)

Animal Genetics and Breeding (30 records)

Animal Ecology (18 records)

Animal Structure (1 record)

Animal Physiology and Biochemistry (4 records)

Animal Physiology Nutrition (4 records)

Animal Physiology Growth and Development (6 records)

Animal Physiology Reproduction (16 records)

Animal Taxonomy and Geography (1 record)

Veterinary Science and Hygiene (55 records)

Pests of Animals (21 records)

Animal Diseases (48 records)

Miscellaneous Animal Disorders (4 records)

Fisheries and Aquaculture

Fisheries and Aquaculture General Aspects (21 records)

Fisheries Production (47 records)

Aquaculture Production and Management (34 records)

Aquatic Ecology (3 records)

Agricultural Machinery and Engineering

Agricultural Engineering (4 records)

Farm Layout (-records)

Agricultural Structures (-records)

Agricultural Machinery and Equipment (22 records)

Natural Resources and Management

Nature Conservation and Land Resources (125 records)

Energy Resources and Management (64 records)

Renewable Energy Resources (9 records)

Non-renewable Energy Resources (2 records)

Water Resources and Management (56 records)

Water Resources and Management ([illegible] records)

Drainage (22 records)

Soil Science and Management (32 records)

Soil Surveys and Mapping (4 records)

Soil Classification and Genesis (7 records)

Soil Chemistry and Physics (8 records)

Soil Biology (16 records)

Soil Fertility (21 records)

Soil Erosion, Conservation and Reclamation (18 records)

Meteorology and Climatology (19 records)

Processing

Food Science and Technology (17 records)

Food Processing and Preservation (86 records)

Food Contamination and Toxicology (8 records)

Food Composition (3 records)

Food Additives (records)

Feed Technology (3 records)

Feed Processing and Preservation (4 records)

Feed Contamination and Toxicology (11 records)

Feed Composition (1 record)

Feed Additives (- records)

Processing of Non-food or Non-feed Agricultural Products (4 records)

Processing of Agricultural Wastes (12 records)

Packaging (2 records)

Human Nutrition

Human Nutrition General Aspects (8 records)

Physiology of Human Nutrition (2 records)

Diet and Diet Related Diseases (3 records)

Nutrition Programmes (1 record)

Pollution

Pollution (4 records)

Occupational Diseases and Hazards (1 record)

Methodology

Mathematical and Statistical Methods (3 records)

Research Methods (8 records)

Surveying Methods (9 records).

Accessibility: No restrictions

Africa Productive Sector Growth and Environment

URL: http:/ /www.info.usaid.gov/sdpsge/psgehome.html

Compiler: Productive Sector Growth and Environment (PSGE) Division of USAID

Content: Promotes African development through research, analysis, and strategic field support in the areas of agriculture, the environment, natural resources management, and private sector development. Provides general information on its program, staff, and partners.

Accessibility: No restrictions

Comment: Material dated

World Resources Institute (WRI)

URL: http://www.wri.org/wri/index.html

Compiler: World Resources Institute

Content: The World Resources Institute is an independent center for policy research and technical assistance on global environmental and development issues. This site provides summaries of WRI projects, including sustainable agriculture, and indicators and trends. Copies of WRI's publications are posted, as is *World Resources 199697,* a report by WRI, UNEP, UNDP, and the World Bank.

by WRI, UNEP, UNDP, and the World Bank.

Accessibilitv: No restrictions

C. Indigenous Knowledge

Centre for Indigenous Knowledge and Rural Development

*URL:*http://www.physics.iastate.edu/cikard/cikard.html

Compiler: Centre for Indigenous Knowledge for Agriculture and Rural Development (CIKARD)

Content: Provides online publications and searchable databases for publications and articles dealing with Agroforestry (382K); Aquatic Resources (122K); Biodiversity (65k); Ecology (428K); Ethnobotany (188K); Natural Resource Management (215K); Rainforest (74K); Soil (392K); Sustainable Agriculture (440K); Traditional Medicine (165K); and Water Management (214K).

Accessibility: No restrictions on viewing databases

Indigenous Knowledge Home Page

URL: http: / /nemesis.nufficcs.nl/ik-pages/

Compiler: Centre for International Research and Advisory Networks (CIRAN)

Content: Provides search capability to approximately 200 indigenous knowledge resources that have been indexed by CIRAN, and provides listings of potentially relevant mailing lists and newsgroups.

Accessibility: No restrictions

Indigenous Knowledge and Development Monitor

*URL:*http:/www.nufficcs.nl/ciran/ikdm/

Compiler: Centre for International Research and Advisory Networks (CIRAN)

Content: The Indigenous Knowledge and Development Monitor is a series of newsletters and articles aimed at those with an interest in the role of indigenous knowledge and participatory approaches to sustainable development. It provides an instrument for the exchange of information, a platform for debate on the concept of indigenous knowledge in a variety of disciplines, and an overview of activities in the field of indigenous knowledge and sustainable development. The Monitor is published three times a year; there are two regular issues and one special issue. The Monitor first appeared in February 1993. Vol. 1 (13) and Vol. 2 (12) are no longer available.

*Accessibility:*No restrictions on viewing articles

Appendix 1
What Is Sustainable Land Management?

Land provides an environment for agricultural production, but it is also an essential condition for improved environmental management, including source/sink functions for greenhouse gases, recycling of nutrients, amelioration and filtering of pollutants, and transmission and purification of water as part of the hydrologic cycle. The objective of sustainable land management (SLM)1 is to harmonize the complementary goals of providing environmental, economic, and social *opportunities* for the benefit of present and future generations, while maintaining and enhancing the *quality* of the land (soil, water, and air) resource (Smyth and Dumanski, 1993). Sustainable land management is the use of land to meet changing human needs (agriculture, forestry, conservation), while ensuring the long-term socioeconomic and ecological functions of the land.

Sustainable land management is a necessary building block for sustainable agricultural development, and it is a key element in AGENDA 21's goal of sustainable development (see Chapter 10). Sustainable agricultural development, conservation of natural resources, and promotion of sustainable land management are key objectives of the new World Bank rural investment program, *From Vision to Action* (World Bank, 1997), and increasingly these objectives are being included in all agricultural development and natural resources management projects.

Sustainable land management combines technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns, so as to simultaneously:

- Maintain and enhance production (productivity)
- Reduce the level of production risk and enhance soil capacity to buffer against degradation processes (stability/resilience)
- Protect the potential of natural resources and prevent degradation of soil and water quality (protection)
- Be economically viable (viability)
- Be socially acceptable and assure access to the benefits from improved land management (acceptability/equity).

1 The concept of sustainable land management (SLM) grew out of a workshop in Chiang Rai, Thailand, 1991. This workshop recommended forming an international working group of the International Society of Soil Science (ISSS) to refine the concept, develop a definition, and to recommend a procedure to monitor and evaluate our progress towards sustainable land use systems. A second workshop (Lethbridge, Canada, 1993), emphasized development of indicators of sustainable land management as instruments for monitoring and evaluation. The results of these experiences were brought together at the XVth Congress of Soil Science, Acapulco, 1994. Subsequent international workshops (Cali, Colombia, 1995; Nairobi, Kenya, 1995; Washington, D.C., 1996, Naurod Germany, 1997) focused on indicators of land quality as part of the suite of required SLM indicators. A third workshop (Enschede, 1997), set the stage for the "next steps" in the development and application of sustainable land management.

The definition and these criteria, called pillars of SLM, are the basic principles and the foundation on which sustainable land management is being developed. Any evaluation of sustainability has to be based on these objectives: productivity, stability/resilience, protection, viability, and acceptability/equity (Smyth and Dumanski, 1993). The definition and pillars have been field-tested in several countries and were judged to provide useful guidance to assess sustainability.

The lack of a comprehensive, quantifiable definition for sustainable land management is sometimes considered to be a serious deficiency. Yet as argued by Gallopin (1994), a research model for sustainability has to be more flexible, and therefore less easy to quantify, than a research model for chemistry, physics, or classical agronomy. Such a research model must be designed around an evaluation process (rather than a thematic context), because it is intended to test the likelihood of certain events taking place and the aggregate impacts of these events, rather than specifics of various null hypotheses or the impacts of certain inputs or land management interventions. Essentially the research model must include a goal statement, a conceptual framework, a set of procedures, and criteria (indicators) for diagnosis. One of the main objectives of such a research model is to evaluate the impacts of events which are uncertain, but the process of evaluation is guided by scientifically defined protocols.

Principles and Criteria for Sustainable Land Management

Experiences gained from field projects in developing and developed countries have identified a series of principles (lessons learned) for sustainable land management, which can be used as general guidelines for development projects (Dumanski 1994, 1997; World Bank 1997). The most useful of these are summarized below.

Global Concerns for Sustainability

Sustainability can be achieved only through the collective efforts of those immediately responsible for managing resources. This requires a policy environment that empowers farmers and other local decisionmakers to reap benefits for good land-use decisions and also to be held responsible for inappropriate land uses.

Integration of economic and environmental interests in a *comprehensive* manner is necessary to achieve the objectives of sustainable land management. This requires that environmental concerns be given equal importance to economic performance in evaluating the impacts of development projects and that reliable indicators of environmental performance be developed.

There is an urgent need to resolve the global challenge to produce more food to feed rapidly rising global populations, while at the same time preserving the biological production potential, resilience, and environmental maintenance systems of the land. Sustainable land management, if properly designed and implemented, will ensure that agriculture becomes a part of the environmental solution, rather than remaining an environmental problem.

Sustainable Agriculture

More ecologically balanced land management can achieve both economic and environmental benefits, and this must be the foundation, or linchpin, for further rural interventions (investments). Without good land management other investments in the rural sector are likely to be disappointing.2 At the same time, arguing for the continued maintenance of agriculture without reference to environmental sustainability is increasingly difficult. Indicators of land quality are needed to guide us along the way.

2 Sustainable land management requires a long-term commitment to maintaining the quality of the land resource; unfortunately, short-term economics often promote technologies that exploit and degrade the land.

Agricultural intensification is often necessary to achieve more sustainable systems. This requires shifts to higher value production, or higher yields with more inputs per unit of production, and higher (more knowledge-intensive) standards of management. However, sustainable agriculture has to work within the bounds of nature, not against them. Many yield improvements can be achieved by optimizing efficiency of external inputs rather than trying to maximize yields.

The importance of off-farm income should not be underestimated because it (a) supplements cash flow on the farm, (b) generates an investment environment for improved land management, and therefore, (c) reduces production pressures on land.

Sharing Responsibilities for Sustainability

Farmers and land managers must expand their knowledge of sustainable technologies and implement improved procedures of land stewardship. The preferred option is not to tell the farmer what to do (command and control legislation), but to create an enabling environment through policy interventions that frees farmers to make the right choice. A policy environment that empowers farmers and also holds them accountable for achieving the objectives of sustainable land management is essential. However, sustainable land management is the responsibility of all segments of society. Governments must ensure that their policies and programs do not create negative environmental impacts, and society needs to define requirements for land maintenance and develop a "social" discount rate for future land use options that encourages the most sustainable use.

Concerns for sustainable land management go beyond agriculture to include the legitimate interests of other aspects of land stewardship, including wildlife, waterfowl, and biodiversity management. There is increasing evidence that society is demanding that farmers become stewards of rural landscapes and that agriculture become more than simply putting food on the table. Many of society's environmental values may not represent economic gains for farmers, however, and farmers cannot shoulder all the costs of environmental maintenance.

Relationship among Soil Quality, Land Quality, and Sustainable Land Management

New concepts of soil and land quality3 are emerging and are often used interchangeably. These concepts and their relationships are summarized below, to the extent that some concensus has been reached on how these should be applied.

Soil quality is the capacity of a specific soil to function within natural or managed ecosystem boundaries to sustain plant and animal production, maintain or enhance water quality, and support human health and habitation (SSSA, 1994).

Land quality is the condition, state or "health" of the land relative to human requirements, including agricultural production, forestry, conservation, and environmental management (Pieri and others, 1995).

Sustainable land management combines technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns to simultaneously maintain or enhance production, reduce the level of production risk, protect the potential of natural resources, and prevent (buffer against) soil and water degradation, be economically viable, and be socially acceptable (Smyth and Dumanski, 1993).

These concepts span the scales of detail, application, and levels of integration with socioeconomic data. Soil quality is the most restrictive, followed by land quality and then sustainable land

3 These concepts of "quality" are based on the essential characteristics of soil and land to fulfill human land use requirements, for example, agriculture, forestry, conservation and maintenance of environmental functions. Natural land quality comes from the suitability of land for specified uses, and is not uniform over the landscape; human interventions (land management) can degrade or enhance land quality; changes in land quality are assessed in relation to benchmarks, such as changes from an undisturbed state.

management. Soil quality is effectively a condition of a site, which can be studied using soil data alone. Land quality requires integration of soil data with other biophysical information, such as climate, geology, and land use. Land quality is a condition of the landscape; that is, it is a biophysical property that also includes the impacts of human interventions (land use) on the landscape. Sustainable land management requires the integration of these biophysical conditions (land quality) with economic and social demands. It is an assessment of the impacts of human habitation and a condition of sustainable development.

These are more than simple differences in semantics; the concepts differ in the kinds and scale of processes being described, the data used for input, and the amount and kinds of integration with other disciplines. However, the concepts form a continuum over the landscape and they must be applied for different types and scales of land use.

The Land Quality Indicator (LQI) Program

Assessment of sustainable land management requires appropriate evaluation instruments, such as Land Quality Indicators. However, land quality, like the concept of sustainable land management of which it is a part, requires operational definitions and specific, measureable indicators if it is to be more than an attractive, conceptual phrase.

The World Bank, in collaboration with UNEP, UNDP, FAO, and the CGIAR, is developing a program called Land Quality Indicators (LQIs) as a means to better coordinate actions on land-related issues such as land degradation (Pieri and others, 1995). In the area of economic and social data, and in some cases for air and water quality, indicators are already in regular use to support decisionmaking at global, national, and subnational levels. In contrast, few such indicators are available to assess, monitor, and evaluate changes in the quality of land resources. Land refers not just to soil but to the combined terrain, water, soil, and biotic resources that provide the basis for land use. Land quality refers to the condition, or "health," of land, specifically to its capacity for sustainable land use and environmental management.

The LQI program addresses the dual objectives of environmental monitoring and sector performance monitoring for managed ecosystems (agriculture, forestry, conservation, and environmental management). It is being developed for application at national and regional scales, but it is also part of a larger, global effort on improved natural resources management. The LQI program is being developed in response to the United Nations Conference on Environment and Development, and it fits with Agenda 21 expectations as well those of the Convention to Combat Desertification.

Agricultural cropland, including agroforestry as well as forested lands, range, and pasture lands, is under increasing pressure because of population migrations to marginal land areas and agricultural intensification on existing cultivated lands. Sustainable land use intensification requires the maintenance or enhancement of the productive potential of the land resources. Increases in food supplies must come from agricultural intensification rather than expansion, but this must be done without degrading the land resource on which production depends. The questions are how this should be achieved and how to monitor progress towards this objective in the different agroecological regions of developing countries? LQIs are tools to help us along the way.

In general, but particularly in developing countries, it is essential that scarce resources devoted to land management be used more cost-efficiently and that policymakers have at least rough indicators of whether environmental conditions and land quality are getting better or worse. Land quality indicators such as nutrient balance, loss of organic matter, land use intensity and diversity, and land cover are useful to task managers and decisionmakers to monitor and improve the performance of projects with respect to their socioeconomic and environmental impacts and to assess the trend toward or away from land-use sustainability.

While routine project performance indicators based on cost-benefit analyses (input-output factors, risk and economic performance indicators) are necessary to monitor the activities and components of a project, LQIs are required to evaluate the environmental impact(s). The quantitative

assessment of physical impacts, such as depletion of soil nutrients, loss of organic matter, soil erosion, water contamination, and so forth may appear to be costly and cumbersome during project implementation, but the long-term negative impact of reduced land quality, such as decreased efficiency of fertilizers, increased erosion, increased fuel consumption, increased pest infestation (nematodes, and so on), often result in rehabilitation costs that are much higher. The LQI approach focuses on preventive maintenance rather than rehabilitation and provides the methodology and approach to integrate the socioeconomic and biophysical information required for better-informed sustainable land management strategies.

The development of LQIs follows a logical framework, providing information not only on the state of the resources, but also on the underlying causes (or "pressure") as well as the response of society to the state and pressure exerted on the land resources. Because of the nature and complexity of land issues, the LQI program recommends addressing issues of land management by agroecological zones (Resource Management Domains4 or "Terroirs"). This new approach puts the focus on evaluating impacts of human interventions on specific landscapes rather than emphasizing only biophysical variables, as was the case in the past. At the same time, this spatial stratification favors incorporating farmer and other local knowledge into the overall process of improved agricultural and environmental land management.

A research strategy for the Land Quality Program was developed during a two-day research planning meeting in Washington, D.C. in 1996, sponsored by the World Bank. A panel of internationally acclaimed scientists and administrators established objectives and priorities for the research, defined strategic alliances to be developed with ongoing national and international programs, and identified potential sources of funding. They also reached agreement on a core set of strategic land quality indicators.

Core LQIs for managed ecosystems (agriculture and forestry) in the major agroecological zones (AEZs) of tropical, subtropical, and temperate environments recommended for development in the short term include:

Nutrient balance. Describes nutrient stocks and flows as related to different land management systems used by farmers in specific AEZs and specific countries.

Yield trends and yield gaps. Describes current yields, yield trends, and actual:potential farmlevel yields for the major food crops in different countries.

Land use intensity. Describes the impacts of agricultural intensification on land quality. Intensification may involve increased cropping, more value-added production, and increased amounts and frequency of inputs; emphasis is on management practices adopted by farmers in the transition to intensification.

Land use diversity (agrodiversity). Describes the degree of diversification of production systems over the landscape, including livestock and agroforestry systems; reflects the degree of flexibility (and resilience) of regional farming systems and their capacity to absorb shocks and respond to opportunities.

Land cover. Describes the extent, duration, and timing of vegetative cover on the land during major erosive periods of the year. Land cover is a surrogate for erosion, and along with land use intensity and diversity, it will offer increased understanding on issues of desertification.

A second set of core LQIs were recommended for longer-term research. These are indicators that require further development of their theoretical base or lack adequate data for immediate development.5 They include:

4 The following definition of Resource Management Domains was developed at an international workshop held in Kuala Lumpur, August 2125,1996: "A Resource Management Domain is a spatial (landscape) unit for identification and application of resource management options to address specific issues. It is derived from geo-referenced biophysical and socioeconomic information, and it is dynamic and multiscale in that it reflects human interventions in the landscape".

5 Only general indicator themes (rather than specific indicators) have been identified so far, along with some preliminary criteria.

Soil quality. Likely to be based on soil organic matter turnover, particularly the dynamic (microbiological) carbon pool most affected by environmental conditions and land use change.

Land degradation (erosion, salinization, compaction, organic matter loss). These processes have been much researched and have a strong scientific base, but reliable data on extent and impacts are often lacking.

Agrobiodiversity. Involves objectives of managing natural habitats and the coexistence of native species in agricultural areas, maintaining natural soil micro and mesobiodiversity, and managing the gene pools utilized in crop and animal production.

Four additional sets of core LQIs were identified, but these were recommended to be developed through collaboration with the respective authoritative disciplines:

Water quality

Forest land quality

Rangeland quality

Land contamination/pollution.

The above are the biophysical components of sustainable land management. Although useful in their own right, they must still be complemented with indicators of the other pillars of sustainable land management: economic viability, system resilience, and social equity and acceptability. Considerable additional work is required to develop these pillars to the same level of detail as the land quality (biophysical) indicators.

Appendix 2
Applications of Indicators for Rural Development Projects

Indicators may be used for ex-ante or ex-post analysis of the sustainability of land management practices, monitoring soils or erosion processes, or impact assessment of various project activities.

Indicators may be used for ex-ante analysis; for example, in project planning. The impact of new land management practices on land quality and the sustainability of land-use systems can be predicted and compared with the effects of current land-use systems. Baseline data on the project region and research results are required for this purpose.

Indicators may also be used for ex-post analysis; for example, in project evaluation. Two or more data sets, at the beginning and the end of the intervention, are compared.

Indicators may be used to monitor the performance of new land management practices or the impact of projects, innovative programs, and agricultural policies supporting sustainable land use. Time series of data are needed for this purpose. An estimate of the time required to prove enhancement of sustainability is necessary prior to data collection. If it is unlikely that this can be achieved before the expiration of the project, precautions must to be taken to ensure that the counterpart organizations will pursue the necessary activities.

The indicators for ex-ante or ex-post analysis do not have to be identical to those used for monitoring after the project terminates. In the first case, available information is a limiting factor, whereas additional information can be generated for monitoring. Thus the indicators can be improved step by step.

Use and Users of Indicators

Indicators provide assistance in decisionmaking for farmers/pastoralists, project planners/ managers or political decisionmakers. Repeated collection and processing of data is costly and therefore only justified if the information is relevant for decisionmaking processes. Even data of excellent quality is irrelevant if there is neither the interest nor the capacity to make use of them in decisionmaking. Involvement of users in defining indicators and monitoring changes increases their interest in using indicators. Indicators are used either for baseline studies (for example, project feasibility studies or evaluations) or for trend analyses undertaken during monitoring or impact assessment.

Scales or Levels

Land-use decisions are made on different levels: farm, community, district (corresponding to project or region), national, and international. Farmers/pastoralists are the main decisionmakers, as it is they who decide whether or not innovations will be applied. Information derived from long-term monitoring of benchmark sites assists land users in deciding whether or not to adopt innovative land management technologies. Rural development projects operate mostly at the district level. Project managers and district governments need information at this level to assist in decisionmaking. This could be data on the extent of pasture degradation, deforestation, soil losses, or nutrient depletion under certain cropping systems.

Agricultural policies and programs such as soil conservation programs, fertilizer subsidies, or controlled input supply are formulated at the national level. However, national policies are being increasingly framed and somewhat controlled by international negotiations, as defined by agreements on trade, conventions, and treaties. Also, central governments are gradually decentralizing control because of fiscal and other constraints, and this process of decentralization must be considered in developing indicators for practical application. This trend is also reflected in the tendency of bilateral donors to withdraw from central government institutions and strengthen local institutions.

Costs of Evaluation

Even when indicators are available, they are often not applied due to the disproportional costs and efforts of monitoring, processing, evaluating, and utilizing the information. When defining indicators and appropriate assessment methods, the costs for the required well-trained staff, transport, equipment laboratory, and data-processing facilities are often neglected or underestimated. These costs can be substantial, and it is important to ensure that counterpart organizations will be able to continue monitoring even after the project terminates. Therefore relevant, easy-to-handle indicators and cost-efficient monitoring and evaluation methods (such as participation of farmers/pastoralists) are needed.

Form of Indicators (Reliability of Data)

Quantitative indicators are preferred as they are perceived to be simple, clear, accurate, and valid. However, reliable quantitative data are rare in most developing countries. Sampling, handling, analysis, and interpretation may be biased due to inexperienced or poorly trained personal and lack of appropriate equipment and materials. Data collection only makes sense if a certain quality is guaranteed.

Qualitative indicators have the advantage of providing richness and intuitive understanding that numerical data cannot convey. But this assessment may be even more demanding than that of quantitative indicators. In addition, qualitative indicators are more difficult to present, and therefore may appear less accurate than quantitative data.

Time Frame

While the collection of baseline data requires surveys of a limited duration, the monitoring of soil quality or the extent of soil erosion requires continuous observation, analysis, and data processing. Thus monitoring is costly.

The ecological and socioeconomic sustainability of new management technologies can be proven only after a period of at least ten years, which is often after the expiration of the development project. Thus monitoring or impact assessment methods need to be tailored to allow counterpart organizations to continue even without the technical and financial assistance of the project. The same is true in regard to data storage. Data needs to be stored in a way that allows access and use for prolonged periods for other interested institutions or donor agencies planning new development projects.

Focus on Community Level

Monitoring land degradation or the impact of improved land management practices can be done locally; for example, on reference fields or farms. Participatory land-use planning and technology development requires the use of local knowledge for monitoring and the participation of land users' data collection.

Indicators based on local knowledge may differ from region to region, depending on the environment, farming systems, and traditions. Consequently it may be difficult to compare indicators applied in different regions. Data aggregation from local or regional levels to national or international levels may become complicated or impossible to evaluate. Data aggregation requires standardized information and often does not consider local peculiarities and knowledge.

Agriculture is unlike other resource-based industries in that it is made up of millions of smallscale entrepreneurs who make individual decisions on the management of their (natural) resources and investment of their capital. Although the land-use decisions of any individual farmer may seem to be insignificant, these decisions are repeated over and over again in the landscape and collectively can achieve major regionaland even globalsignificance. Agriculture is often cited as part of the environmental problem, and it is recognized that agricultural land-use systems are often significant contributors to nonpoint pollution and environmental degradation.

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