Main menu

Land quality indicators and their use in sustainable agriculture and rural development

ISSN 1024-6703

FAO LAND AND WATER BULLETIN

5

WORLD BANK

UNITED NATIONS ENVIRONMENT PROGRAMME

UNITED NATIONS DEVELOPMENT PROGRAMME

undp

Food and Agriculture Organization of the United Nations

FAO FIAT PANIS

Reprinted 1998

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M-50
ISBN 92-5-103975-5

Foreword

This report is ostensibly about land quality indicators (LQIs). However, anyone who reads it will find a useful compilation of advice, experience and opinion on why land quality information is important for sustainable development and how it can be used more effectively for planning and decision making. But the report also poses as many questions as it answers, which in itself reflects the diversity of viewpoints on indicators.

The LQI programme is a joint initiative of FAO, UNDP, UNEP and the World Bank aimed at assisting planners and policy-makers in countries to make better use of their existing information on land quality and to promote more systematic data and information collection.

There remain important questions which are unresolved. How to respond to the diverse data needs of different user groups (from farmers to politicians); the need for better understanding of linkages among biophysical, social and economic indicators; how to address issues of data aggregation, gaps in coverage, and poor data quality. Many of these will probably remain with us for some time, awaiting more research and country experience.

Ms. Schomaker provides a useful overview of some of the issues relating to the use of indicators and Mr. Dumanski lays out the main elements and challenges involved in successfully implementing a land quality indicators programme at the international level.

Mr. Shaxson's paper is revealing for the very distinct and different perspectives of the farmer and the policy-maker. He makes a persuasive argument that, in the end, it is the person on the land who decides how to use it and will manage the land more carefully if he or she can experience the benefits of good land management through improved understanding and use of indicators.

A final element in the report will be found in the papers by Mr. Sombroek and by Mr. Brinkman which mention the concept of resource management domains (RMD). Although not described in detail, RMDs have strong appeal as a means for overcoming the disciplinary boundaries that limit progress in developing indicators of sustainability. They offer a framework for delineating geographic areas based on identifiable biosphysical, social and economic characteristics. The areas can be village territories, a large-scale irrigation area, an undeveloped land area or may cross boundaries. Beyond the ability to link and display spatially different types of information, one attraction is that a number of the tools required for doing this type of analysis are already in hand. We hope that future work on LQIs can report on progress in applying the RMD concept.

Unfortunately, it was not possible in this report to include papers on FAO work under way with respect to sustainable forest management indicators and the rural development database that is being compiled. These are two essential components of land quality and, hopefully, this gap can be filled as the work progresses.

Stein Bie, Director
Research, Extension and Training Division

Robert Brinkman, Director,
Land and Water Development Division

Acknowledgements

The idea for a meeting on land quality indicators originated with Jose Benites, Land and Water Development Division, who subsequently teamed up with Jeff Tschirley, Research, Extension and Training Division, to jointly sponsor and organize the workshop with the assistance of Alexia Baldascini. As with most efforts like this, many other persons were involved.

Wim Sombroek and Stein Bie were instrumental in providing direction, support and technical opinion. Robert Brinkman and a wide array of technical officers in FAO's Statistics, Fisheries Resources and Forest Resources Divisions, contributed much technical perspective on the subject. Many had been working directly or indirectly with indicators for some time but had not had the opportunity to meet. We regretted that, in the effort to cover much subject matter, there was not more time for in-depth discussion.

Also valuable was the perspective provided by Julian Dumanski, Agriculture and Agri-Food, Canada, who with Christian Pieri of the World Bank is promoting LQI programmes, Miriam Schomaker of the United Nations Environment Programme, Roel Oldeman of the International Soil Reference and Information Centre and Francis Shaxson, a consultant with wide field experience. Serge Garcia contributed a paper to this volume on *Indicators for Sustainable Development in Fisheries*, a subject that could not be covered during the workshop. Each has contributed particular experience as a user or producer of land resources information.

Special thanks are due to George Bokeloh for serving as the workshop facilitator and to Lynette Chalk-Contreras for her very capable and efficient preparation of the text and formatting of this document and Chrissi Redfern for the final copy editing.

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Acronyms

AEZ	Agro-ecological Zoning
ALES	Automated Land Evaluation System
ASSOD	Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia
CABI	Commonwealth Agricultural Bureaux International (UK)
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture (CGIAR, Colombia)
CRES	Centre for Resources and Environmental Studies
CSD	Commission on Sustainable Development (UN)
DEM	Digital Elevation Model
DPCSD	Department for Policy Coordination and Sustainable Development (UN)
EBRD	European Bank for Reconstruction and Development
EMAP	Environmental Monitoring and Assessment Program
ENRIN	Environment and National Resources Information Network
EPA	Environmental Protection Agency (USA)
EPIC	Erosion Productivity Impact Calculator
EROS	Earth Resource Observation System
ERS	Economic Research Service (USDA, USA)
EU	European Union
FESLM	Framework for Evaluating Sustainable Land Management
FAO	Food and Agriculture Organization of the United Nations (UN)
GCOS	Global Climate Observing System
GEF	Global Environmental Facility
GEMS	Global Environmental Monitoring System
GEO	Global Environment Outlook
GIS	Geographic Information System
GLASOD	Global Assessment of the Status of Human-induced Soil Degradation
GOOS	Global Ocean Observing System
GRASS	Geographic Resources Analysis Support System
GRID	Global Resource Information Data Base
GRT	Gross Registered Tonnage
GTOS	Global Terrestrial Observing System
IBSRAM	International Board for Soil Resources and Management (Thailand)
ICRAF	International Center for Research in Agroforestry (CGIAR, Kenya)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (CGIAR, India)
ICSU	International Council of Scientific Unions
IDRC	International Development Research Centre (Canada)
IFPRI	International Food Policy Research Institute (CGIAR, USA)
IGBP	International Geosphere-Biosphere Programme
IIASA	International Institute for Applied Systems Analysis (Austria)
IIED	International Institute for Environment and Development (UK)
IISD	International Institute for Sustainable Development (Canada)
IITA	International Institute of Tropical Agriculture (CGIAR, Nigeria)

IJC	International Joint Commission (EPA, USA)
ILO	International Labour Office (UN)
ILRI (a)	International Institute for Land Reclamation and Improvement (Netherlands)
ILRI (b)	International Livestock Research Institute (CGIAR, Kenya and Ethiopia)
IMF	International Monetary Fund
ISCO	International Soil Conservation Organization
ISIS	ISRIC Soil Information System
ISRIC	International Soil Reference and Information Centre (Netherlands)
ISSS	International Society of Soil Science
ITC	International Institute for Aerospace Survey and Earth Sciences (Netherlands)
ITE	Institute of Terrestrial Ecology (UK)
IUCN	World Conservation Union
LQI	Land Quality Indicators
MCS	Monitoring, Control and Surveillance
MSY	Maximum Sustainable Yield
NASA	National Aeronautics and Space Administration (USA)
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration (USA)
NOVIB	Netherlands Organization for International Development Corporation
NRCS	Natural Resources Conservation Service (USA)
OECD	Organisation for Economic Co-operation and Development
PSR	Pressure-State-Response
RIVM	National Institute for Public Health and the Environment (Netherlands)
RMD	Resource Management Domain
SARD	Sustainable Agriculture and Rural Development
SCOPE	Scientific Committee on Problems of the Environment
SI	Sustainability Indicator
SLEMSA	Soil Loss Estimation Model for Southern Africa
SOTER	Soil and Terrain Digital Database
SRS	Sustainability Reference Systems
UNCLOS	United Nations Convention on the Law of the Sea
UNCED	United Nations Conference on Environment and Development
UNDPCSD	United Nations Department for Policy Coordination and Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial and Development Organization
UNSO	United Nations Sudano-Sahelian Office
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
WAICENT	World Agricultural Information Centre (FAO)
WASWC	World Association of Soil of Water Conservation
WB	World Bank
WCED	World Commission on Environment and Development
WISE	World Inventory of Soil Emission Potentials
WMO	World Meteorological Organization (UN)
WOCAT	World Overview of Conservation Approaches and Technologies
WRI	World Resources Institute (USA)
WWF	World Wide Fund for Nature

Summary report and conclusions

A workshop entitled *Land Quality Indicators for Sustainable Resource Management* held in FAO Headquarters, Rome was attended by FAO technical staff and invited participants from the Agriculture Canada, International Soil Reference and Information Centre, United Nations Environment Programme, World Bank, and private consultants. The workshop provided a technical forum to discuss issues relating to land quality indicators (LQIs) and their use by planners and policy-makers. LQIs can be used at the national and district levels to assess the qualities of land, to monitor its changing conditions, and to formulate policies and development programmes that take land quality into account.

Progress was made toward preparing a workplan for an LQI Programme including country case studies, development of a meta-database, research topics, location and funding of the Secretariat, financing, institutional contacts, membership in the Core Advisory Committee and follow-up activities.

INTRODUCTION

There is much concern that land quality is changing, but there is not much formal monitoring of what is changing, in 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.

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, to develop linkages among the natural resources, social and economic dimensions and especially to make it more easily accessible among the developing countries.

J.R. Benites, Land and Water Development Division, and
J.B. Tschirley, Research, Extension and Training Division,
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THE WORKSHOP

Objectives

The specific workshop aims were to:

; 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.

Participants

The participants represented eight FAO Divisions: Animal Production and Health (AGA), Land and Water Development (AGL), Plant Production and Protection (AGP), Agriculture and Economic Development Analysis (ESA), Fishery Resources (FIR), Forest Resources (FOR), Rural Development (SDA), and Research, Extension and Training (SDR), as well as the Agriculture Canada, International Soil Reference and Information Centre (ISRIC), United Nations Environment Programme (UNEP), World Bank, and several consultants. The list of participants is detailed on page 205.

Programme

The workshop used formal presentations, discussion sessions and case studies to cover about 16 subjects in three sessions:

; Recent efforts to develop indicators.

; Sectoral issues in developing indicators.

; Thematic issues in developing indicators.

An external facilitator guided the discussions.

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 socio-economic 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 are to be found. The lower the level the more detailed the indicators become.

The amount of detail which needs to be recorded increases as one moves along the sequence of questions: (1) Is any change occurring, and in what direction - positive or negative? (2) What is changing? (3) How great is the change? (4) How rapidly is it occurring? (5) What processes of change are in motion? (6) Why have these processes of change been set in motion?

The pressure - state - response framework (PSR) was generally accepted, but questions were raised about its limitations in terms of cause/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 request 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 the 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 labelled 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 analysed and interpreted material are credible and, if unexpected or unusual, backed by specific supporting evidence (quality assurance);

; preparing brief, concise and clear narrative material which is timely and designed for the specific target audience.

Valuable data are useless if they are not analysed and presented in a decision-support context. On the other hand, an excess of analysis using statistical techniques misapplied to data that do not fulfil 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 (e.g., 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.

FORMULATION OF WORK PLAN

A meeting of the core LQI co-sponsors was held to discuss options, prepare a short-term workplan for the programme, financial support for programme activities, location of the Secretariat, main institutional contacts, and membership in a Core Advisory Committee.

To date, the following proposals have been submitted for funding:

; development of global metadata information system to the Netherlands Government;

; case study in temperate regions of China to the Canada Government;

; technical support to the LQI secretariat and a case study in West Africa to the French Government;

; a joint FAO-UNEP project has been implemented to develop an integrated approach to planning and management of land resources as part of FAO's responsibility as UN Task Manager for implementation of Chapter 10 of Agenda 21[1].

Other support might be possible from Norway (Norwegian Aid Society for International Development: NORAD) for South America, from Denmark, Germany (German Agency for Technical Cooperation: GTZ), the Swiss Government, Australia (Australian Agency for International Development: AusAid) and the United States Agency for International Development (USAID). Enquiries would also be made with foundations: Rockefeller and Ford as well as Kellogg, MacArthur and McNamara.

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1 Programme of Action for Sustainable Development, signed at the United Nations Conference held in Rio de Janeiro, June, 1992.

FAO, Land and Water Development Division (AGL), agreed to pursue the following areas of work to assist in development of LQIs:

; refinement of the AEZ zonation to include at least one more level of detail;

; refinement of estimates of land suitable for cultivation (development of more stringent criteria) and characterization of potential arable lands;

; refinement of the "anticipated yield" calculation.

WORKSHOP FOLLOW-UP

1. An Indicators Working Group should be established to elicit inputs and participation from a range of technical units for the LQI initiative.

2. A detailed workplan should be prepared for the LQI programme.

3. Guidelines for LQI country case studies should be developed as soon as possible; FAO, Research, Extension and Training Division (SDRN) should take the lead on this.

4. An LQI Core Advisory Committee (CAC) of scientific advisers should be established to develop and guide the LQI programme. Membership would be *ad personam*, and would be no larger than 10 - 12 members.

5. It was recommended that a transitional period of about a year be used to launch the LQI programme. During this time the World Bank would play a key role in bringing together the technical groups and organizations, and seek funding. During the first quarter of 1997 the Secretariat would be transferred to FAO-Rome. The model used by the Technical Advisory Committee (TAC) Secretariat of the Consultive Group on International Agricultural Research (CGIAR) was considered appropriate to the LQI initiative in terms of providing a rapid response and access to high-quality personnel.

Session 1

Recent efforts to develop indicators

Land resources evaluation and the role of land-related indicators

THE FRAMEWORK FOR LAND EVALUATION

Land quality assessment and land evaluation have been important programmes in FAO since its foundation in 1945. By 1970 many countries had developed their own systems of land capability classification and land evaluation, making international exchange and comparison of information difficult. Some form of standardization was obviously required. The International Institute for Land Reclamation and Improvement (ILRI) in Wageningen, which had traditionally concentrated on water issues, now wanted to pay more attention to "land" issues and sought contact with FAO for that purpose. This resulted in a joint project to develop a *Framework for Land Evaluation,* published in 1976.

The Framework drew substantially from earlier concepts and methodologies developed, e.g., in Brazil and Iran. It was subsequently applied in many countries in which FAO was active through UNDP-financed projects, and also in several bilaterally financed projects on natural resources inventories and evaluation.

In the years following publication of the Framework, detailed guidelines were published for its application for forestry, rainfed agriculture, irrigated agriculture, and extensive grazing (FAO, 1983; 1984; 1985; 1991). *Guidelines for Land-use Planning* were published as FAO Development Series 1 (FAO, 1993a).

During these years the concepts, principles and definitions of *land, land utilization types, land qualities, land suitability classification and land evaluation procedures* were already specified but in some circles the notion of a single, overall "land quality" in the sense of health-of-land has come to the fore.

Discussing differences in approach, and reconfirming or adapting existing concepts and definitions is one purpose of the present meeting. A second purpose is to raise awareness within FAO about interest in the World Bank (WB), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and the United Nations Commission on Sustainable Development in the use of indicators for sustainable agriculture and rural development. A third purpose is to inform these same organizations of FAO technical activities relevant to indicators.

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ASSESSMENT OF LAND AND SOIL DEGRADATION

A second relevant historical development is the Global Assessment of Soil Degradation (GLASOD). The initiative was launched by UNEP, in 1987, in cooperation with the International Society of Soil Science (ISSS) and FAO. It resulted in the International Soil Reference and Information Centre (ISRIC) in Wageningen producing, at short notice and on the basis of admittedly incomplete knowledge, a credible global assessment of human-induced soil degradation. With the support of about 250 correspondents from all regions of the world this resulted in a world map (average scale 1:10M; 3 sheets and explanatory note: Oldeman, Hakkeling and Sombroek 1991; Oldeman 1992), showing causative factors, type, degree, rate and geographic extent of soil and land degradation. It was meant to be a quick and rough first attempt and did not deal with off-site effects, but it successfully raised public awareness of the problem of land degradation. The results were amply used, if not over-used, in the discussions related to the UN Conference on Environment and Sustainable Development in Rio de Janeiro, 1992; in the World Resources Institute's publications; in UNEP's World Atlas of Desertification (Middleton and Thomas, 1992), and in FAO's study Agriculture Towards 2010 (Alexandratos, 1995). It also illustrated the need for better, quantitative information and an assessment of the social and economic consequences of land degradation, and prompted the International Soil Conservation Organization (ISCO) to start with a World Overview of Conservation Approaches and Technologies (WOCAT).

AGENDA '21

The United Nations Conference on Environment and Development (UNCED) meeting in Rio resulted in a series of new initiatives on assessment of sustainability and resilience of land resources, by institutions such as the Commonwealth Agricultural Bureaux International (CABI) on soil resilience and sustainable land use (Budapest meeting: Greenland and Szabolcs, 1994); by the International Board of Soil Research and Management (IBSRAM) on an international Framework for Evaluating Sustainable Land Management (FESLM, FAO, 1993b) and on integrated soil-water-plant nutrient management research (SWNM, Greenland *et al.*, 1994), and by the World Bank on land quality indicators. The latter initiative is based on two regional meetings (Cali, Colombia; Nairobi, Kenya) and an inter-agency meeting in Washington in June 1995 which resulted in concrete proposals for action.

UNCED's Agenda 21 itself (1993), as agreed upon by participating governments, specifies desired actions on environmental protection and sustainable development, including the land-cluster of chapters 10 to 14. Chapter 10, called "An integrated approach to land resources planning and management", is meant to provide the over-arching approach to the more sectoral land-use issues (on mountains, forests, deserts, rainfed agriculture, etc.). FAO is Task Manager for most of these chapters, and the Land and Water Development Division (AGL) is the focal point for Chapter 10. It resulted in a progress report by the UN Secretary-General during the second Substantive Session of the UN Commission for Sustainable Development (CSD) in April 1995, and also in a background publication by FAO itself, with substantial input by other FAO staff and correspondents of other UN organizations such as UNEP and Habitat (FAO, 1995). This, in turn, led to a joint UNEP/FAO project on promoting integrated land-use planning at national and local level in developing countries, with special attention to socio-economic issues and participatory approaches.

CONCEPTS, DEFINITIONS AND PRINCIPLES

"Land", the "functions of land", "land evaluation", "land qualities", "sustainability", "resilience", etc. need to be defined carefully to avoid confusion and to assure effective cooperation between international institutions and national planning entities that deal with the assessment of changes in land conditions.

The holistic concept of *Land* was already recognized in the Framework for Land Evaluation (FAO 1976), repeated implicitly in UNCED's chapter 10 of 1993, and formally described in FAO 1995. It reads:

> "Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)."

The various *functions* of land are also described in FAO's 1995 background paper:

> The many functions of Land:
>
> - production function
> - biotic environmental function
> - climate-regulative function
> - hydrologic function
> - storage function
> - waste and pollution control function
> - living space function
> - archive or heritage function
> - connective space function

; land is the basis for many life support systems, through production of biomass that provides food, fodder, fibre, fuel, timber and other biotic materials for human use, either directly or through animal husbandry including aquaculture and inland and coastal fishery (the *production* function);

; land is the basis of terrestrial biodiversity by providing the biological habitats and gene reserves for plants, animals and micro-organisms, above and below ground (the *biotic environmental* function);

; land and its use are a source and sink of greenhouse gases and form a co-determinant of the global energy balance - reflection, absorption and transformation of radiative energy of the sun, and of the global hydrological cycle (the *climate regulative* function);

; land regulates the storage and flow of surface and groundwater resources, and influences their quality (the *hydrologic* function);

; land is a storehouse of raw materials and minerals for human use (the *storage* function);

; land has a receptive, filtering, buffering and transforming function of hazardous compounds (the *waste and pollution control* function);

; land provides the physical basis for human settlements, industrial plants and social activities such as sports and recreation (the *living space* function);

; land is a medium to store and protect the evidence of the cultural history of humankind, and source of information on past climatic conditions and past land uses (the archive or *heritage* function);

; land provides space for the transport of people, inputs and produce, and for the movement of plants and animals between discrete areas of natural ecosystems (*connective space* function).

Land has attributes, characteristics, properties and qualities (or limitations/ conditions):

; an *attribute*, or *variable*, is a neutral, over-arching term for a single or compound aspect of the land;

; a *characteristic* is an attribute which is easily noticed and which serves as a distinguishing element for different types of land; it may or may not have a practical meaning (e.g., soil colour or texture, or height of forest cover are characteristics without giving direct information on land quality);

; a *property* is an attribute that already gives a degree of information on the value of the land type;

; a *land quality* (or limitation) is a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use.

Defined as such, land qualities are not absolute values, but have to be assessed in relation to the functions of the land and the specific land use that one has in mind. Some examples:

i. land recently cleared from forest has a positive quality in respect of arable cropping (clearing, as "development costs", adding to the value of potential agricultural land), but has a negative quality in respect of sustainable use of the natural vegetative cover;

ii. land with a high degree of short-distance variation in soil and terrain conditions has a positive quality for biodiversity, is a large drawback to large-scale mechanized arable farming, but has a smaller limitation - or even an advantage - for smallholders' mixed farming;

iii. the presence of scattered clumps of trees or shrubs in an open savannah area with harsh climatic conditions is a positive quality for extensive grazing (shelter against cold, heat or wind) but may be less important, or negative, for arable farming;

iv. the presence of small land parcels, of woody or stony hedgerows and terraces, or of archaeological remains, is a positive quality in relation to the archival function of the land, but can conflict with its production function;

v. the propensity of the soil surface to seal and crust is a negative quality for arable farming (poor seedbed condition; reduced moisture intake of the soil), but is an asset of the land as regards water harvesting possibilities for crop growing in lower parts of the landscape wherever rainfall is submarginal.

A listing of the various land qualities in relation to crop growth, animal production, forest productivity and inputs/management levels is already given in the *Framework for Land Evaluation* of 1976 as shown in Table 1.

TABLE 1
Examples of land qualities

LAND QUALITIES RELATED TO PRODUCTIVITY FROM CROPS OR OTHER PLANT GROWTH

- Crop yields (a resultant of many qualities listed below).
- Moisture availability.
- Nutrient availability.
- Oxygen availability in the root zone.
- Adequacy of foothold for roots.
- Conditions for germination.
- Workability of the land (ease of cultivation).
- Salinity or sodicity.
- Soil toxicity.
- Resistance to soil erosion.
- Pests and diseases related to the land.
- Flooding hazard (including frequency, periods of inundation).
- Temperature regime.
- Radiation energy and photoperiod.
- Climatic hazards affecting plant growth (including wind, hail, frost).
- Air humidity as affecting plant growth.
- Drying periods for ripening of crops.

LAND QUALITIES RELATED TO DOMESTIC ANIMAL PRODUCTIVITY

- Productivity of grazing land (a resultant of many qualities listed under "Atmospheric qualities" in Table 2).
- Climatic hardships affecting animals.
- Endemic pests and diseases.
- Nutritive value of grazing land.
- Toxicity of grazing land.
- Resistance to degradation of vegetation.
- Resistance to soil erosion under grazing conditions.
- Availability of drinking water.

LAND QUALITIES RELATED TO FOREST PRODUCTIVITY

The qualities listed may refer to natural forests, forestry plantations, or both.

- Mean annual increments of timber species (a resultant of many qualities listed under "Atmospheric qualities" in Table 2).
- Types and quantities of indigenous timber species.
- Site factors affecting establishment of young trees.
- Pests and diseases.
- Fire hazard.

LAND QUALITIES RELATED TO MANAGEMENT AND INPUTS

The qualities listed may refer to arable use, animal production or forestry.

- Terrain factors affecting mechanization (trafficability).
- Terrain factors affecting construction and maintenance of access-roads (accessibility).
- Size of potential management units (e.g. forest blocks, farms, fields).
- Location in relation to markets and to supplies of inputs.

Another listing, related to the vertical components of a natural land unit, is given in FAO (1995), and shown in Table 2. A similar one can be developed for horizontally defined qualities.

TABLE 2
Land qualities related to vertical components of a natural land unit

ATMOSPHERIC QUALITIES

Atmospheric moisture supply: **rainfall**, length of growing season, evaporation, dew formation.

Atmospheric energy for photosynthesis: **temperature**, daylength, sunshine conditions.

Atmospheric conditions for crop ripening, harvesting and land preparation: **occurrence of dry spells**.

LAND COVER QUALITIES

Value of the standing vegetation as "crop", such as **timber**.

Value of the standing vegetation as germ plasm: **biodiversity** value.

Value of the standing vegetation as **protection against degradation of soils and catchment**.

Value of the standing vegetation as regulator of local and regional climatic conditions.

Regeneration capacity of the vegetation after complete removal.

Value of the standing vegetation as **shelter** for crops and cattle against adverse atmospheric influences.

Hindrance of vegetation at introduction of crops and pastures: the **land "development"** costs.

Incidence of above-ground pests and vectors of diseases: **health risks** of humans and animals.

LAND SURFACE AND TERRAIN QUALITIES

Surface receptivity as seedbed: the **tilth condition**.

Surface treatability: the **bearing capacity** for cattle, machinery, etc.

Surface limitations for the use of implements (stoniness, stickiness, etc.): the **arability**.

Spatial regularity of soil and terrain pattern, determining size and shape of fields with a **capacity for uniform management**.

Surface liability to deformation: the occurrence or hazard of **wind and water erosion**.

Accessibility of the land: the degree of **remoteness** from means of transport.

The presence of open freshwater bodies for use by humans, animals or fisheries.

Surface **water storage capacity of the terrain**: the presence or potential of ponds, on-farm reservoirs, bunds, etc.

Surface propensity to yield run-off water, for local **water harvesting** or downstream water supply.

Accumulation position of the land: degree of **fertility renewal or crop damaging** by overflow or overblow.

SOIL QUALITIES

Physical soil fertility: the net **moisture storage capacity** in the rootable zone.

Physical soil toxicity: the presence or hazard of **waterlogging** in the rootable zone (i.e. the absence of oxygen).

Chemical soil fertility: **the availability of plant nutrients**.

Chemical soil toxicity: **salinity** or salinization hazard; **excess of exchangeable sodium**.

Biological soil fertility: the **N-fixation capacity** of the soil biomass; and its capacity for **soil organic matter turnover**.

Biological soil toxicity: the presence or hazard of **soil-borne pests and diseases.**

Substratum (and soil profile) as **source of construction materials**.

Substratum (and soil profile) as **source of minerals**.

Biological soil toxicity: the presence or hazard of **soil-borne pests and diseases.**

SUBSTRATUM OR UNDERGROUND QUALITIES

Groundwater level and quality in relation to (irrigated) land use.

Substratum **potential for water storage** (local use) and conductance (downstream use).

Presence of unconfined freshwater **aquifers**.

Substratum (and soil profile) **suitability for foundation works** (buildings, roads, canals, etc.)

A *land utilization type* (FAO, 1976) is a kind of land use described or defined in a higher degree of detail than that of a major kind of land use (such as rainfed agriculture or forestry), as an abstraction of actual land-use systems (which may be single, compound or multiple).

Land evaluation is the process of assessment of land performance when used for specific purposes, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation.

Land evaluation should combine the various qualities/limitations of the land in relation to the envisaged use or non-use. Obviously, the relative value of all land qualities has to be *weighted* for each of such uses. For the physico-chemical qualities of the land, such as the net soil moisture storage capacity, the availability of plant nutrients, or the land surface arability, this weighting can be done quantitatively. For a number of the bio-environmental qualities such as biodiversity or archival values a qualitative assessment is necessary which may be non-tangible in an economic sense. For instance, "wetlands" may have an important ecological value, but if one has a thousand or more small wetland units in a country such as Rwanda, then their individual value depends on whether all these wetlands are of the same type or whether they are all different. Also, the upland forests of central Amazonia may have a "surplus" value of biodiversity, but all or most of them may still be necessary to ensure their climate- or hydrology-regulative function.

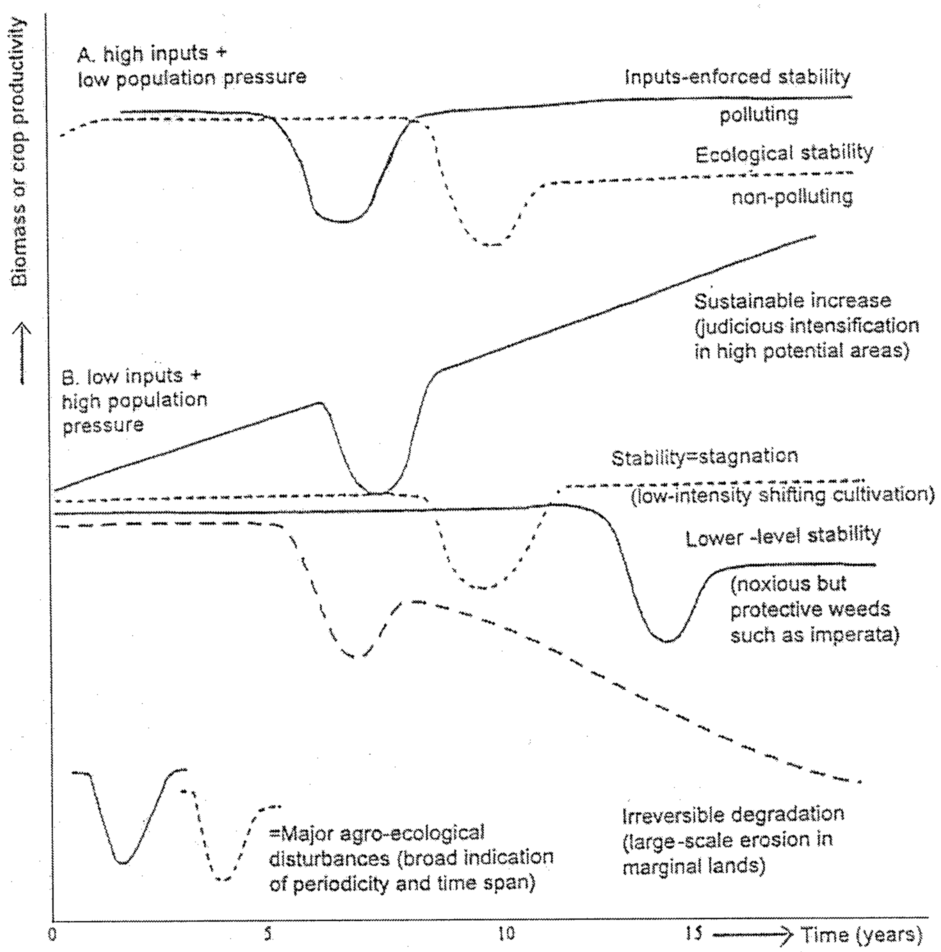
Finally, regarding *sustainability* of land "quality" or land "health", again land health depends on the function or functions that one considers from an environmental point of view, or for sustained use by an increasing human population in relation to food security and their well-being in an intergenerational context.

Sustainability does not necessarily imply a continuous stability of productivity level, but rather a *resilience* of the land; in other words: the capacity of the land to recover quickly to former levels of productivity - or to resume the trend to increased productivity - after an adverse influence such as drought, floods, or human abandonment or mismanagement (Figure 1).

Degradation of land has to be considered in the same context. The GLASOD criteria for degrees of land degradation tried to specify resilience as follows:

1. Light degradation: The terrain has somewhat reduced agricultural suitability, but is suitable for use in local farming systems. Restoration to full productivity is possible by modifications of the management system. Original biotic functions are still largely intact.
2. Moderate degradation: The terrain has greatly reduced agricultural productivity but is still suitable for use in local farming systems. Major improvements are required to restore productivity. Original biotic functions are partially destroyed.
3. Strong degradation: The terrain is non-reclaimable at farm level. Major engineering works are required for terrain restoration. Original biotic functions are largely destroyed.

FIGURE 1
Some concepts of resilience of land and its productivity, comparing the situation in some industrialized countries (A) with that of most developing countries (B). Source: Sombroek, 1993



4. Extreme degradation: The terrain is unreclaimable and beyond restoration. Original biotic functions are fully destroyed.

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The context of indicators in FAO

THE CONCEPT OF SUSTAINABLE DEVELOPMENT

Since 1987, when the Brundtland Commission, World Commission on Environment and Development (WCED) defined sustainable development as meeting the needs of the present, without compromising the ability of future generations to meet their own needs, many different definitions have been proposed. While it is interesting to devise theoretical concepts of sustainable development, it is more difficult to determine what needs to be done to achieve it.

Sustainable development means sustaining human well-being over time. An essential corollary of this statement is the requirement that actions taken now which are likely to have negative repercussions on future human well-being be associated with a concrete form of compensation for the future. Since capital provides the means for the achievement of well-being, many experts of sustainable development agree that this compensation implies the transfer of capital stock from current to future generations. The issue of sustainability therefore translates into providing future generations with at least as much capital per caput as the current generation has (Serageldin, 1995).

The total capital we strive to sustain within and between generations consists of separate components:

; the natural capital (the land, the water, the air, genetic material, ecosystems, etc.);
; the human capital (knowledge, science, culture, health, nutrition);
; the institutional capital (schools, universities, research facilities, infrastructure);
; the social capital (democracy, good governance, civil rights, equity, social harmony).

The level of substitution between these components is an issue for debate. It is immediately obvious that only moderate substitutions may be sensible.

MEASURING SUSTAINABLE DEVELOPMENT

Putting sustainable development into practice means changing the ways in which decisions are made to allocate resources information is essential and indicators play a fundamental role in this context by acting as pointers to reveal conditions and trends in the development of a household, a community, a country or groups of countries. Indicators are a means to an end. They guide planners in making decisions about using their nation's

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resources. Traditional economic indicators (consumption, savings, investment, etc.) by themselves provide a distorted picture of progress and must be complemented by environmental and social measures.

In recent years, there has been a call for greater monitoring of nations' natural resources. This is especially relevant for poor developing economies which are dependent on their natural resource base for much of their income. In agriculture-dependent countries, environmental degradation and poverty may go hand in hand. The need to meet immediate food demand often leads to over-exploitation of the environment. Consequently the supply of basic agricultural goods and services is reduced, thus generating more poverty. And the cycle continues.

It is therefore essential that all countries but particularly developing countries take into account and closely monitor their natural assets (and the changes in these) through the use of indicators on land, water, forestry, fisheries, etc. In sustainable agriculture and rural development the integration of economic, social and environmental information into planning and decision making translates into integrating statistics on net farm productivity with measures of the natural and human resources in agricultural projects and their off-site environmental trends.

INITIATIVES UNDERTAKEN BY AGENCIES TO DEVELOP INDICATORS RELATED TO SUSTAINABLE DEVELOPMENT

Probably the most ambitious undertaking with respect to indicators of sustainable development is being coordinated by the UN Department for Policy Coordination and Sustainable Development (UNDPCSD). They have organized a number of technical meetings among organizations such as FAO, the World Bank, UNEP, Scientific Committee on Problems of the Environment (SCOPE), World Resources Institute (WRI), and Eurostat to identify indicators for each relevant chapter of the Agenda 21. About 140 indicators have been identified and agencies have been preparing methodology sheets on how to calculate them. In late 1996 testing of the indicators in selected countries began.

UNEP has a number of activities under way related to indicators. One initiative of special interest is focusing on the establishment of national programmes in countries of the Mediterranean region in conjunction with the Mediterranean Action Plan (METAP sponsored by European Bank for Reconstruction and Development (EBRD), European Union (EU), UNEP, WB). Countries are identifying a variety of indicators, primarily environmental ones relating to air, land, water and waste, that reflect national priorities. The interesting point is that beyond its monitoring and assessment objectives, a major component of the programme focuses on capacity building to collect, analyse and use indicators for planning and decision making. Approximately one-third of the programme will be dedicated to this important issue.

The World Bank also has a number of indicator initiatives under way, not the least of which relates to land quality. They have also established a unit that deals specifically with indicators.

The Organisation for Economic Co-operation and Development (OECD) is widely known for its effective use of indicators in producing the State of the Environment report. It was the driving force behind the development and application of the pressure-state-response framework (PSR) which is being used by a number of organizations in their indicator work. Other departments of the OECD are also developing indicators relating to agriculture and to rural development.

NGOs, too, have interests in the development and use of indicators. However, with the exception of the larger international NGOs (e.g., WRI, SCOPE, World Conservation Union: IUCN), their role so far has been rather limited. How to promote greater involvement at the national and sub-national levels is a valid topic for debate at this meeting.

The main reason for mentioning some of the above activities is that they have all adopted the PSR framework as their basis for organizing and applying indicators. In our view, the PSR has a number of important limitations when used at the national and sub-national levels for assessing or monitoring sustainable development. Thus, it is important to have a full discussion of the PSR, and other frameworks, at this meeting:

INDICATORS IN FAO

The literature on the methodology for developing indicators stresses the importance of making best use of existing methods and sources of data. FAO is the principal source of many kinds of natural resource data related to developing countries, and must therefore take advantage of this position to develop useful indicators. Some examples of how existing FAO data might be used to develop environmental indicators follow.

- *Changes in area harvested of annual crops* This statistic could be calculated by summing the areas of the individual crops, already reported by FAO. It may reflect or be an indicator of the expansion of agriculture onto more environmentally sensitive lands, or into forested areas;

- *Intensity of timber production* A combination of an estimate of natural regeneration and harvest data, this statistic is an indicator of the rate of depletion of a renewable resource that is often open-access;

- *Changes in fish harvests, by species and location* In combination with an estimate of natural regeneration of the stock and other oceanographic factors, this variable can reflect pressure on fish populations.

An important question we must ask ourselves is: where does FAO's comparative advantage lie in developing indicators for sustainable development? At the global level? At the national level? Or at the district and farm levels? Work in the different technical divisions of FAO is contributing to the development of indicators at each of these levels although the main emphasis is on building national indicators.

The Forestry Department, for example, is actively supporting the work of the Intergovernmental Panel on Forests (established within the framework of the Commission on Sustainable Development) in issues related to *criteria and indicators for sustainable forest management*. Qualitative or quantitative indicators monitor current forest management practices and their effects. The criteria are the principles of sustainable forest management against which the sustainability of forests may be assessed.

Criteria and indicators are being developed at the national and forest management unit levels. Indicators at the national level attempt to help policy-makers in reaching informed decisions regarding sustainability programmes including long-term forest management. Forest management unit level indicators are directly concerned with site-specific performance criteria and management practices. Whilst national criteria of specific forest areas have a wider scope and should not be used directly to regulate forest management in detail, it is clear that forest management indicators should be consistent with those at the national level. Clearly the two, although with somewhat different aims, are closely inter-related and need to be studied together.

The FAO Forestry Department assists intergovernmental panels, governments and NGOs by giving technical advice on the soundness and adequacy of the proposed criteria and indicators of sustainable forest management. An additional FAO initiative is to seek ways and means of involving countries and regions currently not covered by the ongoing national initiatives on criteria and indicators for sustainable forest management. These include the arid and semi-arid areas of Africa and Asia; Caribbean and Central American areas; and small island countries. Finally, the Forestry Department has been involved in developing global indicators such as forest area, protected forest area and harvesting intensity related directly to Chapter 11 (Combating deforestation) of Agenda 21, but also to the activities in Chapter 12 (Combating desertification and drought), Chapter 13 (Sustainable mountain development) and Chapter 15 (Conservation of biological diversity).

In Fisheries, the objective has been to locate and quantify the potential for subsistence and commercial warm water fish farming in ponds. National governments and financing institutions need information on where aquaculture development is most promising before committing scarce resources to development. A study has been carried out by FAO for Africa and a similar analysis will be repeated for Central and South America. Briefly, fish farming potential is assessed on the basis of temperature regimes, availability of surface water for storage in ponds, suitability of topography (mainly slope of land) and soil texture for pond construction, availability and variety of agricultural by-products as inputs, and local market potential. It is clear from this list that elements of land quality texture, slope, erosion- and the agricultural (crop and husbandry) systems on the land directly affect the quantity and quality of water for fishing.

The Statistics Division (ESS) is primarily responsible for consolidating and publishing many of the official data necessary to build indicators of sustainable development. So, for example, the extent of land characterised by over-grazing could not be measured and used for policy-making if planners did not have information on the number of animals populating given areas. However, the more direct relevance of ESS to indicator development lies in its intention to produce a manual on "Agricultural-Environmental Statistics and Indicators" for the use of countries. This manual would guide national statistical offices and assist them in compiling, interpreting and presenting indicators in the area of sustainable agriculture clearly bringing out what is essential, what is not wanted, and what is the context in relation to each indicator.

The emphasis here is on indicators for use at the national level. However, this is not to say that sub-national and local level information is ignored. The Farm Management and Production Economics Service, for example, is using the changes in farming systems which have occurred over the last twenty years in the Usambara area in Tanzania to analyse which quantitative and qualitative data should go into creating indicators related to this field.

ISSUES FOR DISCUSSION

Level of aggregation of information

The question of when and when not to aggregate indicators is important in managing sustainability. Usually, indicators are considered part of an information pyramid going from detailed local information to more aggregated information at the national and global levels. Aggregation affects the quantity and quality of information that is passed along to decision-makers. When considering information it is critical to determine whether its aggregation will have a significant effect on the decision-making outcome. For example, at the farm level, in analysing the effect of fertilizer input on crop yields, the tendency is to focus on total fertilizer use instead of considering a more disaggregated indicator on the composition of the fertilizer (nitrogen, phosphate), which could be more relevant to determining crop productivity. Again, at a national level, the wrong indicators can suggest inappropriate policies for the resolution of food security problems. If fertilizers are applied to responsive lands to increase crop production, national figures may show an overall improvement but, in local terms, regions already producing satisfactory crops would be ameliorated, while the low-yielding areas (usually where the rural poor are located) would remain with low productivity.

Geo-referenced information

The identification of natural geographic units is important in natural resource management. Watersheds, for example, have long been identified as the preferred unit for integrated water resources management (World Bank, 1993, OECD, 1989). In a watershed, the upper land use practices are linked to the resource systems downstream through the hydrological cycle. As a result, many of the impacts (e.g., siltation of the river bed, deposition of chemical residues, flooding and droughts), which would be ignored in traditional project analyses, are accounted for when the watershed approach is used.

These natural biophysical units however rarely coincide with administrative units. The latter must not be ignored because they contain important social and economic information which determines how natural resources are used and managed. The challenge therefore consists of taking the data on production and natural resource management which is usually classified by administrative units, and geo-referencing them (i.e., transforming them to fit natural geographic units through the use of geographic information systems) to an agro-ecological zone, watershed or other geographic unit.

Linkages among economic, social and environmental factors

The use of indicators must be tailored to deal with specific issues regardless of the level of analysis. The most widely used framework at present is the pressure-state-response framework which is well adapted to an issues-oriented approach.

Let us take the issue of nutrient mining as an example. Nutrient mining is the unsustainable extraction of nutrients from the soil (for example, through logging, cropping or ranching). It requires that new land be constantly brought under production as nutrients are extracted in the forms of logs, crops or meat, while old, mined land is abandoned. One of the driving forces of this process is shifting cultivation with fallow periods that are too short for full recovery. The *state* or resulting condition is the state of the forest and the *response* or mitigating action could be to reduce government subsidies for cash crops.

To state simply that shifting cultivation with shortened fallows is the driving force of the problem does not help us identify appropriate solutions. The issue of why these farmers indulge in such an environmentally destructive land use is fundamental and must be analysed in the context of social and economic factors.

Firstly, in deciding whether to conserve or develop their lands, the individual farmers have no incentive to take account of the external benefits of forest conservation (such as watershed protection, erosion resistance and conservation of biodiversity, to name a few) because they accrue in unmarketed form (i.e., they have no direct price or market). This situation is further exacerbated in developing countries because governments may assume many of the costs of establishing the activity which involves forest land clearance through spending on infrastructure (e.g., building roads into forests), promoting financial aid to settlers and manipulating farm prices to lower food costs in urban areas.

In addition, the difficulty for these farmers to get access to credit, and the uncertainty regarding their rights to the resources, will further influence the farmers to undertake shifting cultivation instead of a more sustainable activity.

The review, with other agencies and NGOs linkages among economic, social and environmental factors in building indicators for sustainable development, will need to be addressed in this workshop. We trust that a common basis for future work will be found. No doubt there are still gaps to be filled, some of which relate closely to recent conventions on biodiversity and on desertification. Examples are:

; estimates for the value of genetic erosion
; estimates for the value of undiscovered benefits.

These, and other challenges, must form the basis for close collaboration among interested parties, and FAO is certainly willing to play its part.

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Development of environmental indicators in UNEP

This presentation will go slightly beyond the issue of indicators and consider the entire array of information and data collection, management, and analysis, since they are all relevant to indicators for assessing and reporting on sustainable development. First the United Nations Environment Programme (UNEP) setting will be outlined, then a number of indicator-related issues will be touched upon as part of assessment and reporting, finishing with a listing of specific UNEP work on land quality indicators.

GENERAL UNEP SETTING

It should be realized that UNEP, unlike FAO, is not an implementing agency. Its main role is in catalyzing actions, liaison and conflict resolution. UNEP tries to promote activities by providing small financial contributions resulting in joint outputs, by jointly developing frameworks others can link up to and by providing expert advice. All its activities take place as joint efforts with other institutions (both within and outside the UN; at international, regional and national level). UNEP's mission is broad, working mostly at global and regional levels and covering "the environment" as a whole:

> "To provide leadership and encourage partnership in caring for the environment by inspiring, informing and enabling nations and people to improve their quality of life without compromising that of future generations."
>
> Within this general context UNEP's assessment mandate is:
>
> "To keep under review the state of the world environment (SOE); enhance understanding of the critical linkages between environment and human activities;identify priorities for international action; flag emerging issues; and strengthen national, regional, and global information handling capacities."

UNEP's assessment framework for fulfilling this mandate can be illustrated in Figure 1, in which all groups of activities needed for integrated assessment and reporting are reflected. Often there are not enough reliable, well structured, easily accessible data available; often progress made in a project or programme is based on expert opinion and educated guesswork. Besides, there are no straightforward, internationally-agreed methodologies for integration of natural resources data with socio-economic data; for

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scale integration (both spatial and temporal); and for change indicators. Assessment efforts still tend to take place on an isolated case study or subject level. There are, among others, different schools of thought, different methodologies, different entry points, data availability and compatibility problems, scale problems and different ways of presenting information.

In the current situation the assessment triangle looks more like a pinnacle and perhaps even an up-side-down one: information used to take decisions often originates from weak data and analysis. Eventually we would want the pinnacle to look like a more stable triangle (Figure 2).

FIGURE 1
Providing the knowledge base for decision making

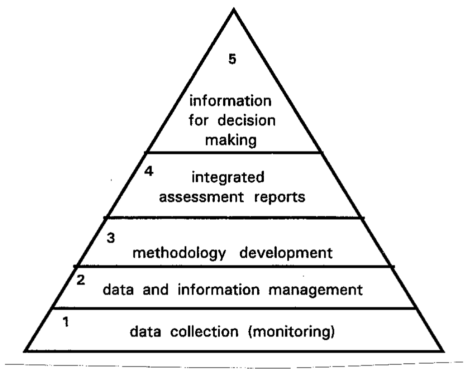
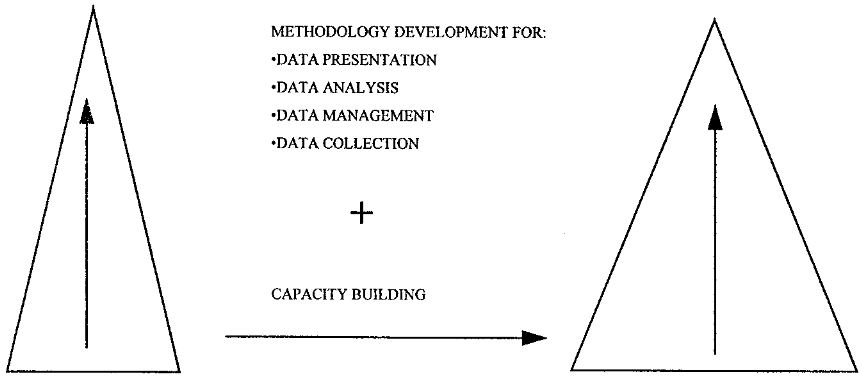


FIGURE 2
From pinnacle to triangle



INDICATORS WITHIN OVERALL ASSESSMENT AND REPORTING FRAMEWORK

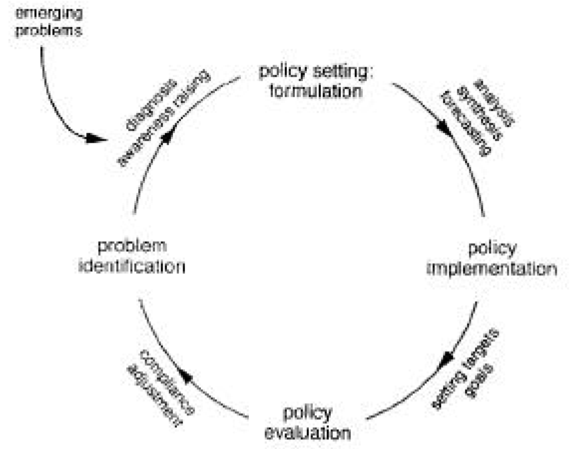
To move from pinnacle to triangle we need to: (i) continue efforts to further develop operational, practical data collection and data management tools; analysis, integration and modelling methodologies; indicators and presentation formats; and (ii) continue efforts to enhance capacities in the entire assessment process. An enormous challenge lies ahead.

Issues, often interrelated, involved in data and information management for and assessment of for instance land quality can be summarized as follows:

1. user relevance;
2. integration;
3. scale issues;

4. methodological and science issues;
5. data issues;
6. assessment capacity.

FIGURE 3
The decision-making cycle (adapted from Winsemius 1986, in RIVM/UNEP, 1995)



User relevance

Many assessment activities still take place within the realm of science. More direct links are necessary between the actual users and producers of information. Assessment activities should preferably be formulated together with users, in fact upon the request of users (for their purposes). Depending on who wants to know, different levels of detail and different forms of information are needed. Once the "why" is clear the kind of data needed can be decided upon. Users are often considered in the context of the decision-making cycle which includes four stages (Figure 3).

Decision-making processes take place at all levels of government and involve many different cultural, social, institutional, economic and environmental inputs and considerations. Depending on what level and which stage in the cycle, the kind of information needed differs.

For problem identification and awareness raising, general descriptive indicators are needed. But even then, different audiences need customized material; for instance to reach national policy-makers one would opt for a different presentation than for the general public.

For strategy, policy, project formulation one would need more detailed indicators, also focusing on the causes of a certain problem and on projections of impacts, through modelling, scenarios, cost-benefit and multi-criteria analysis, so that effective, and realistic, responses can be formulated.

For the actual implementation of land quality related policies, goals and targets need to be established at national and local level (more quantitative indicators). Here the social and economic context becomes increasingly important. The people living on the land will have to decide on what is needed and on how and when they want to and can reach certain targets. Assessment and information aspects should focus on negotiation to agreement on targets among all the stakeholders who in various ways have interests in the land.

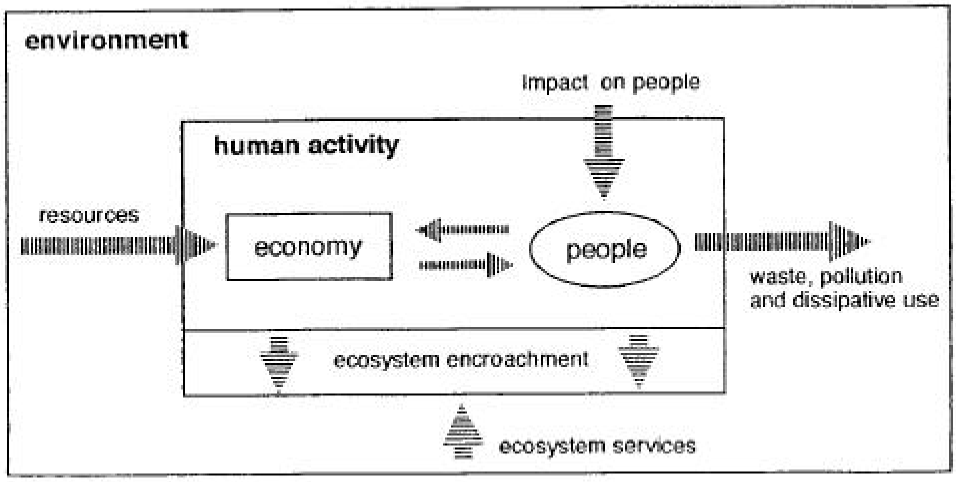
To evaluate the effectiveness of policies and actions, one needs to find quantitative indicators that illustrate how the situation has changed in relation to the goals and targets.

In summary: indicators should clearly serve the specific users and stakeholders, both considering the level of aggregation (from local population to high-level international policy-makers) and the stage in the decision-making cycle.

Integration

Over the past decades UNEP has been focusing on state and trends, with emphasis on environmental sub-systems such as climate, desertification and biodiversity. However, though it is indeed necessary to know where a problem occurs, one also needs to know **why** the problem occurs in order to be able to formulate responses. There is an urgent need to focus more on the inter-linkages between the environmental system and the human system (Figure 4) rather than the individual components. Not only should research and assessment activities cover both sub-systems; inter-linkages between the two are even more important.

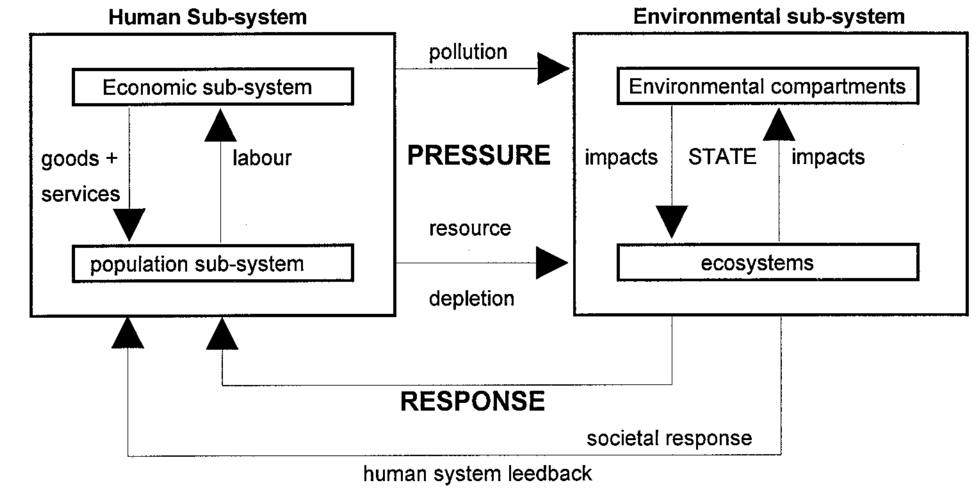
FIGURE 4
A model of human interaction with the environment (RIVM/UNEP, 1995)



Causes of environmental problems and the resulting negative trend are predominantly human induced. Only when the causes and the impacts of the resulting pressures on the system are known can adequate responses be formulated (Figure 5). To qualify and quantify the pressures, state and responses, indicators need to be found that adequately represent the extremely complex situation. The OECD PSR framework (Figure 5) is being adopted by many for such indicator development (even though it cannot properly reflect the real world because linkages are not linear).

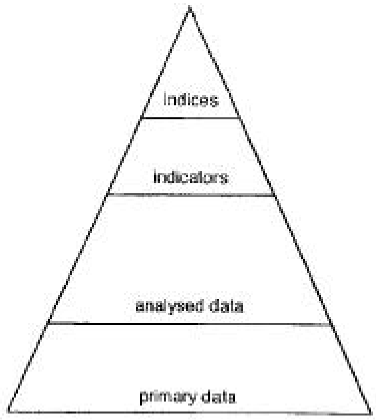
There are potentially hundreds of indicators which could be relevant to land quality and desertification (UNEP/RIVM 1994, UNDP/UNSO/NRI 1995, World Bank/FAO/ UNDP/ UNEP 1995, UNDPCSD 1995 etc). Some cover the causes/pressures part of the system, some focus on change in status and trends and the impacts of such change, and

FIGURE 5
Pressure-state-response framework for indicators (RIVM/UNEP, 1995)



some are related to responses. The challenge before us is to find those core indicators that are sufficiently representative and at the same time easy to understand and measure on a routine basis. To put it differently, indicators should be SMART: **s**pecific, **m**easurable, **a**chievable, **r**elevant and **t**ime-bound. Indicators are needed at different aggregation levels (see also the section on user relevance).

FIGURE 6
The Information/Indicator Pyramid (SCOPE, 1995 and WRI, 1995)



Scale issues

Ideally some persons would want to have detailed data on "everything". We would want to be able to move smoothly from an abundance of detailed field data to summarized information for national level purposes to even more condensed information for sub-regional, regional and eventually global level purposes (the Indicator Pyramid, Figure 6).

For practical reasons (constraints in available time, human and financial resources) we would want to find shortcuts. We would want to determine simple, direct links between field level data, general statistics and remotely sensed data at decreasing levels of detail (through extrapolation, spatial modelling techniques and the like). Once such relationships are established we would be able to monitor over time and to indicate which temporal scales are relevant for which aspects. For many of these wishes there is not yet a response or solution.

Methodological and science issues

This very much relates to the scale issues mentioned above. Most assessment work still takes place on an isolated, scientific case study basis. Methods developed are very site-specific. Work is often carried out within the university realm (PhD studies and the like): an ideal situation where usually more equipment is available than in the real world, where "free" research staff time is at hand, where time pressure may be less acute. As a result, methods developed under these circumstances may not be easily repeatable, not broadly applicable, not realistic in terms of time, cost, and practical applicability within for instance a government or NGO structure, and not suitable to provide an overall picture for larger areas.

Data issues

On the one hand there are not enough data available or being collected on a routine basis; on the other hand, sometimes data are being collected because they have been collected routinely without clear reasons on why they are needed. The quality of data that are available is often questionable: no standardized procedures are followed, guess work is involved and the like. Data are often collected using "self made" definitions and classification systems, as for instance in the case of land use and land cover: data from one area are not compatible with data from other areas, which hampers comparison and presentation of an overall picture. Data may exist but be difficult to get hold of: they are stored in too many different places, are poorly documented and often there is a competition aspect involved. Many data are only available as general statistics and point data while one would ideally want georeferenced information.

Data and information management and assessment capacity

Apart from the need to further develop methodologies for data collection, data management, data analysis and integration, and data presentation, there is a need to strengthen national capacities in all these aspects so that the entire world can eventually contribute to the assessment process on an equal basis.

SPECIFIC UNEP INVOLVEMENT IN INDICATOR RELATED WORK

UNEP work relevant to land quality indicators is listed below, following the five compartments of the Assessment Triangle (Figure 1). Most work is ongoing and is part of UNEP's approved 1996-97 programme. Whether all will be implemented in full will depend on the available funds.

In addition, it should be mentioned that UNEP mainly uses the Environment and Natural Resources Information Networking (ENRIN) programme as the vehicle to strengthen capacities in environmental assessment and reporting and associated data management. This programme develops umbrella frameworks (along the lines of the triangle) for different regions. It encourages major donor institutions in each region to link up and contribute to activities that fit within the umbrella framework. Emphasis is on increasing collaboration among **existing** institutions, programmes and networks (to avoid duplication). Outputs developed elsewhere are promoted through this programme. These can be any relevant successful output from anywhere: datasets, data management software tools (such as the Soil and Terrain Digital database methodology - SOTER), analysis tools or models and decision-making tools.

Databases and monitoring relevant to assessment of, inter alia, land quality

; GEMS/Water and GEMS/Air programmes (air and water quality monitoring networks).

; The planned Global Terrestrial Observing System (GTOS), comparable and linked to the already existing Global Oceans and Global Climate Observing Systems (GOOS and GCOS). Once operational GTOS will provide an excellent umbrella mechanism for data collection and sharing; co-sponsors are FAO, International Council of Scientific Unions (ICSU), UNESCO, UNEP and World Meteorological Organization (WMO).

; Further methodological development of the GLASOD approach (in Asia); and preparation of (sub-) regional Soil and Terrain Digital databases or shells (SOTER); with ISRIC and FAO.

; World Overview of Conservation Approaches and Technologies (WOCAT) and UNEP's drylands management success stories programme; GLASOD showing the negative side (human-induced degradation) and WOCAT, supported by University of Bern, FAO, several bilateral donors, the positive side (successful responses).

; Digital Elevation Model (DEM): an elevation database from which many products can be derived, a joint USGS-EROS Data Centre, UNEP, National Aeronautics and Space Administration (NASA) product; available for Africa on the WWW; other continents to follow in 1996.

; Land cover characterization using advanced very high resolution radiometer (AVHRR); a joint USGS-EROS Data Centre, UNEP and NASA product, using the International Geosphere-Biosphere Programme (IGBP) processing protocols; Latin America first half 1996; related project implemented for a number of countries in Asia and the Pacific.

; Population distribution (through spatial modelling); with CGIAR and NCGIA.

; Core Data Working Group activities: focus on core data for integrated environment assessments and for UNEP's new Global Environment Outlook reports (see under *Assessment Reports* below).

Data and information management (data access; meta-data; data harmonization; GIS; decision support tools; database structures; etc.)

; Mercure satellite system which will link UNEP's data and information sources to the Internet and World Wide Web facilities, etc. This will improve data accessibility and sharing. System currently being installed.

; Development of meta-data and associated information system for UNEP data and information and for referencing to other data in the world, all in support of assessment and reporting activities. A sub-system for land quality indicators is under consideration (the concepts behind such complicated information systems still need much thought and experimentation).

; UNEP/FAO Initiative on Standardizing Land Cover and Land Use Classification Systems, with the Institute of Terrestrial Ecology (ITE), World Conservation Monitoring Centre (WCMC) and International Institute for Aerospace Survey and Earth Sciences (ITC); a flexible attribute-based approach (including software).

; International Center for Research in Agroforestry (ICRAF), International Institute for Land Reclamation and Improvement (ILRI) and UNEP work on a tool for spatial characterization (a CDROM with a Data Exploration Tool).

Support of methodology development for assessment

; Integration of socio-economic and natural resources aspects and scale integration (case study based, eventually to lead to more generally applicable methodology).

; Indicator development (the issue that links all assessment components together): considering both the biophysical and the social dimensions; contribute to ongoing and new initiatives such as Department for Policy Coordination and Sustainable Development (DPCSD), United Nations Sudano-Sahelian Office (UNSO), SCOPE, International Development Research Centre (IDRC), International Institute for Sustainable Development (IISD), World Bank, FAO, UNEP, UNDP Land Quality Indicators programme, UNEP success story analysis and others. There is an urgent need to bring all these efforts on one line.

; Forecasting/scenarios/modelling: in the framework of the Global Environment Outlook (GEO) process (see GEO below). For instance some modelling work on linking food production and land degradation, but mainly the even more complicated integrated modelling issues.

Assessment reports

; Sectoral assessments, such as: Global Water Assessment; the World Atlas of Desertification.

; Integrated outlooks on the global environment - GEOs: biennial and decadal; replacing UNEP's more traditional state-of-the-environment reports; involving much regional consultation; supported by working groups on data, scenarios, modelling, policy; production process still under development; first trial issue early 1997.

; Technical reports, datasets, software tools, decision-making tools (e.g., indicators) resulting from the work listed above (for instance a whole range of GEMS/Water and GEMS/Air publications both covering specific assessments and methodological material in the form of guidelines and monitoring standards; publications on social dimension issues; the References list directly indicator related publications).

Information sharing

Outputs will be produced as a family of products. The same base material will be customized for specific target groups: brochures, popular environment library booklets, hands-on booklets, newsletters (e.g., EarthViews, Desertification Bulletin), videos, electronic information sharing, summary reports for policy and decision-makers, more elaborated technical reports and basic data for technicians and the scientific community.

The present paper does not cover indicator work in which UNEP is involved in the context of biodiversity, land-based sources of pollution, oceans and coastal areas, forests, etc.

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Application of the pressure-state-response framework for the land quality indicators (LQI) programme

The LQI programme is being developed to harmonize the combined objectives of food production and environmental protection, and is one of several responses to the challenges put forward by UNCED in Agenda 21. Because of its complexity, the programme is being initiated through a coalition of international agencies (World Bank, FAO, UNDP and UNEP). Additional partners are actively being solicited for the programme which will initially focus on LQIs for developing countries.

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 standardized through international scientific protocols, LQIs will be used for policy and programme formulation for district, national and global assessment, environmental impact monitoring, and to promote technologies, policies and programmes to ensure better use of natural resources and sustainable land management.

The LQI initiative is similar in concept to previous programmes sponsored by national and international agencies, such as indicators of economic and social performance and state-of-the-environment reporting. These programmes were initiated by groups of interested parties working together, using an iterative process of indicator development, testing, refinement and standardization. This ultimately resulted in the standard economic, social and environmental indicators that are now used routinely for monitoring national economic performance, and air and water quality. Something similar is planned in the LQI programme for development of indicators for land quality. In this context, land refers not just to soil, but to the combined resources of soil, water, vegetation and terrain that provide the basis for land use. Land quality is the condition or health of the land relative to its capacity for sustainable land use and environmental management.

Although the programme is still new (preliminary activities started in 1994), much has already been accomplished:

1. Two regional workshops (Cali and Nairobi), and one coordination workshop (Washington) have been held. The regional workshops developed and tested some of the pertinent concepts and preliminary indicators for specific agro-environments; the Washington workshop (June, 1995) was the first formal meeting between the World Bank, FAO, UNDP and UNEP to establish the basis for the global coalition necessary to launch the programme.

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2. The Pressure-State-Response (PSR) Framework, used by OECD, SCOPE and other national and international organizations for environmental performance monitoring, has been adopted as the common approach for the programme.

3. A discussion paper, describing the concept of LQIs, some examples of possible LQIs for specific regions, and some recommendations for their development, has been prepared (Pieri *et al.*, 1995).

4. An institutional structure for the programme has been developed consisting of a small secretariat to develop the programme and coordinate activities, a Core Advisory Committee responsible for scientific and methodological standards, and a Donor Support Group to ensure liaison among the partners, identify priorities and ensure coordination and funding.

The objectives of the LQI programme are:

1. To develop a set of standardized LQIs for managed ecosystems (agriculture and forestry) in the major agro-ecological zones (AEZs) of tropical, sub-tropical and temperate environments.

2. To identify sources of data and develop standardized 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 identify the institutional capacity needed for setting and implementing land and natural resources priorities, policies and technologies at district, regional, national and global levels.

The outputs of the programme will be:

1. A core set of LQIs related to major policy-related questions on land management in tropical, sub-tropical and temperate regions.

2. A set of targets and thresholds for the state LQIs to provide guidance towards more sustainable land management for the different eco-regions.

3. A meta-database on land-related information set up on Internet and the World Wide Web, with documentation on what data are stored with which agencies, the quality and reliability of the data, and how the data can be accessed. Emphasis will be on land suitable for cultivation and forestry, biological production potentials, current land management technologies, and other related information necessary to monitor changes in land quality.

4. Assessment of trends in land quality for various AEZs for use at district, national and global levels.

5. Case studies, using data from representative countries, will be an integral part of the programme. Development of regional and district level LQIs through case studies in representative AEZs. The case studies will focus on developing countries selected on the

basis of agro-environments, intensity of land use, and amounts of data available (AEZ x land use intensity x data availability). The case studies will utilize data available from the national census bureaux, but will also include results from on-ground studies being conducted by many of the national and international agencies, including NGOs. Tentatively about six AEZ case studies are being planned.

6. National capacity building: This activity will be closely integrated with capacity building activities being conducted by agencies such as UNEP, FAO, the International Agricultural Research centres and others. Major activities will be training on geo-referenced data acquisition, training on PC-based data management, and training on the use of local farmer knowledge and the development of quantitative indicators from farmer knowledge.

The objective is to complement 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 results of this programme will be used to support planners, decision-makers in national governments, international institutions and donor agencies, NGOs involved in community-level development, and others. Initial activities will focus on decision-makers at district and national levels.

THE WHAT AND WHY OF INDICATORS

Indicators are statistics or measures that relate to a condition, change of quality, or change in state of something valued. They provide information and describe the state of the phenomena of interest, but with a significance beyond that directly associated with an individual parameter (OECD, 1993). Indicators need to be developed according to their perceived applications, and this requires reliable statistics and raw data. Because of regional requirements and priorities, global agreement on a single set of indicators would be difficult and unnecessary for many issues. However, a common aggregate of key indicators could be used as a basis for international comparison (Dumanski, 1994; Bakkes *et al.*, 1994).

A distinction must be made between indicators and other types of statistics (Bakkes, *et al.*, 1994; Eswaran *et al.*, 1994). Measurements of some event or phenomena produce raw data, which after processing are often published as statistics. These statistics can provide underlying information, or they could be indicators if they have some added significance and are tied to a specific problem. If the number of indicators is reduced by aggregating them according to some formula, then these are called indices. Examples of useful indices are the Human Development Index, the Air Pollution Index, the UV Radiation Hazard Index, and the Water Quality Index. Indicators of land quality (LQIs) are statistics which report on the condition and quality of the land resource, but also on the cause-effect relationships which may result in changes in quality and the responses to these changes by society.

LQIs are also needed for the World Bank's new project management called Portfolio Management (OPD, 1993), and for development of Country Assistance Strategies, and National Environmental Action Plans. LQIs need to be embedded in the objectives of a project to ensure that they serve as monitoring instruments during and after the life of the project. Broad level statistics may provide some of the data needed to develop these indicators, but very often some new data will have to be collected, particularly information on how farmers manage their land and the rate of adoption of conservation practices. Criteria for the selection and development of indicators have been developed by many agencies (OECD, 1993; EPA, 1994; Bakkes *et al.* 1994; WRI/UNEP/UNDP, 1994).

AVAILABLE FRAMEWORKS FOR RESOURCE ASSESSMENT

LQIs are part of the family of indicators being developed for environmental reporting. However, along with other types of indicators they are also useful for reporting on the performance of the agricultural sector, because they report on land as part of the production system. A framework of some sort is required to guide the development of LQIs, and to ensure they are relevant to those land management issues in a country.

Frameworks serve to organize the (large quantities of) data used for developing an indicator, to improve the accessibility of the indicator, and to increase its value-added (EPA, 1994). Frameworks can also serve to link individual monitoring programmes, identify duplication and gaps, facilitate development of new indicators and increase the use of this information for development of policies and programmes.

There are currently many frameworks available for reporting on environmental issues. These can be classified as accounting frameworks, reporting frameworks, and sustainability frameworks.

Frameworks for environmental accounting can be :

a. Social (welfare) accounting frameworks - these are true accounting frameworks which reflect resource flows throughout a system, but which have been adjusted to include environmental costs and the distribution of these among economic activities. The social accounting frameworks require balancing inputs with outputs of production by incorporating with economic and environmental costs and to make explicit statements of gains and losses in the system.

b. Environmental (natural resource) accounting or "green" accounting - this is a new accounting approach which requires that GDP or NDP be adjusted for the depreciation (cost) of using natural resources in economic activities (Costanza, 1991; Lutz, 1993). This may involve defensive environmental costs, such as those used for prevention of degradation, as well as user costs for degraded natural resources. Natural resource accounting is linked with the System of National Accounts, and has become an important tool for environmental policies and strategies. A recent extension of this concept, with application to land resources, is to consider costs of degradation and resource consumption as depreciation from nature's endowment of national wealth (Serageldin, 1995).

Frameworks for environmental reporting can be:

a. Models of decision-making processes - these are organizational frameworks which mimic environmental decision making in government and other agencies. They are early forms of environmental reporting frameworks, but they are still used for activities such as the Environmental Monitoring and Assessment Program (EMAP), and in international activities such as the International Joint Commission (IJC) (EPA, 1994).

b. Pressure-state-response (PSR) framework - This framework links pressures on the environment as a result of human activities, with changes in the state (condition) of the environment (land, air, water, etc.). Society then responds to these changes by instituting environmental and economic programmes and policies, which feed back to reduce or mitigate the pressures or repair the natural resource (OECD, 1993). This framework has been adopted by many OECD countries and by the World Bank for environmental reporting. It is described in greater detail in subsequent parts of this paper.

c. Spatial frameworks - this is a general grouping of frameworks consisting of those used solely for monitoring air, water, land, flora and fauna, as well as the various ecological land classification systems which are used for environmental assessment, planning and management. Although readily understandable, they do not adequately reflect ecosystem patterns or processes, and they do not highlight environmental issues of importance to governments. In essence they deal only with the "state" dimension of the PSR approach, without linking this to pressures of human activity or responses of society.

Frameworks for assessing sustainability and sustainable development can be:

a. Agro-ecosystem approach - this approach is based on assessing the performance of agro-ecosystems according to ecological, economic and social dimensions, using four criteria for sustainability, namely productivity, resilience, stability and equity. Crosslinking the flows of resources and materials with the dimensions and criteria for sustainability enables one to assess the performance and the sustainability of agro-ecosystems.

b. Total (factor) productivity - this is the ratio of the value of all outputs divided by the value of all economic and environmental inputs, normalized to remove changes in prices (Lynam and Herdt, 1988; Harrington *et al.*, 1994; Whitaker, 1994). Total productivity is the inverse of the unit cost of agricultural production when the costs of environmental degradation are included. Agricultural systems are deemed to be sustainable when total productivity shows a non-declining trend. This framework has been adapted by several of the CGIAR centres for research purposes.

c. International Framework for Evaluation of Sustainable Land Management - sustainable land management (SLM) describes the complementary goals of maintaining and enhancing the quality of the land, while providing economic, social and environmental opportunities for the benefit of present and future generations. Sustainable land management can be assessed by evaluating the performance of the five pillars of SLM, namely maintenance or enhancement of productivity, reduction of risk, enhancement of environmental (land) quality, economic; viability, and social acceptability (Smyth and Dumanski, 1994). A logical analysis framework is used to accommodate the imprecise concept of sustainability, i.e., assessments of sustainability are inferred in degrees of probability. This framework relates closely to the PSR framework for environmental reporting, and it is being evaluated in a number of case studies throughout the world.

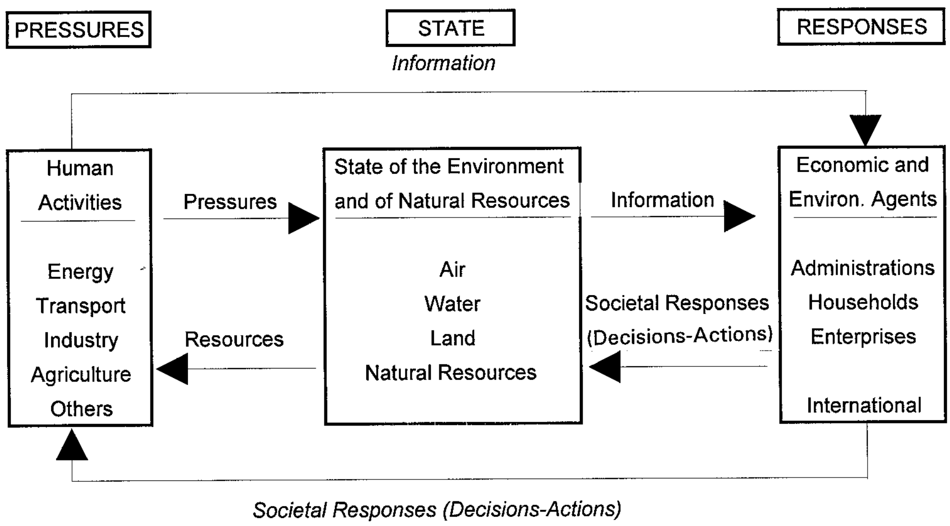
Each framework has a different set of objectives, and each is used for a different purpose. Although sets of indicators are required for each framework, these are somewhat different in each case. The following sections describe some recommended procedures for application of the PSR approach for development of LQIs.

APPLICATION OF THE PRESSURE-STATE-RESPONSE FRAMEWORK FOR DEVELOPMENT OF LAND QUALITY INDICATORS

LQIs report on the biophysical condition of land, but also on how it is being managed and the policy and social environment for instituting improvements in land management or which foster deterioration. This is achieved using the PSR framework.

The PSR framework has been modified slightly and adopted by the World Bank for development of environmental indicators and LQIs (O'Connor, 1994b). For the LQIs, the PSR framework is used to structure and classify information, and to assist in the identification of the key set of indicators that best describe how farmers are managing their lands and the impacts of this management.

FIGURE 1
Pressure-state-response framework



The PSR (Figure 1) is a convenient representation of the linkages among the pressures exerted on the land by human activities (pressure box), the change in quality of the resource (state box), and the response to these changes as society attempts to release the pressure or to rehabilitate land which has been degraded (response box). The interchanges among these form a continuous feed-back mechanism that can be monitored and used for assessment of land quality.

A single index of land quality is neither feasible nor desirable at this time, but groups of indicators can be developed to reflect the PSR dimensions of land quality.

Three groups of LQIs have been developed to reflect the PSR structure:

Group 1. Pressure on the land resource

Indicators in this group include those activities that relate to the degree of intensification and diversification of agricultural land uses, and result in increased pressure on land quality. This may include the number of crops in a cropping system per year or per hectare, type and intensity of tillage, degree of removal of biomass, integration with livestock systems, number of food and fibre products produced annually, etc. These indicators must be seen within the context of major socio-demographic factors such as population pressures, land tenure, etc., but the latter do not qualify for inclusion as LQIs. This is because these major forces do not influence land quality directly, but rather through the land practices that are adopted by farmers as a consequence. It is these management systems and their impacts that we wish to capture as LQIs, although changes in the major driving forces may provide some "early warning" signals.

Group 2. State of land quality

State indicators reflect the conditions of the land as well as its resilience to withstand change as a consequence of sector pressures. This may include indicators which express changes in biological productivity (actual and potential), extent and impacts of soil degradation, including erosion, salinization, etc., annual and long-term balance of nutrients (exported and imported by the cropping systems), degree and type of contamination or pollution (by direct application, atmospheric transport, etc.), changes in organic matter content, water holding capacity, etc. The changes in state may be negative with poor management, or positive with good management.

Group 3. Societal response(s)

The response mechanisms are normally achieved through direct actions by the farmers themselves in evolving or adopting improved land management systems, or through complementary activities whereby adoption of conservation technologies is stimulated by general economic, agricultural and conservation policies and programmes. In rare instances, environmental regulations may be necessary to effect proper control of land resource degradation. Response indicators may include number and types of farmer organizations for soil conservation, extent of change in farm technologies, risk management strategies, incentive programmes for adoption of conservation technologies, etc. Response indicators should be distinguished into those categories promoted by governments, those undertaken by individual farmers and those supported by agri-business.

AVAILABLE DATA AND PROCEDURES FOR DEVELOPMENT OF LQIS

Good baseline information on soils, climate, land use and land management are necessary for developing reliable LQIs. Although this information is often incomplete or lacking in many developing countries, some data are almost always available. Also, several international agencies have collated and organized some of these data in computer compatible formats. These stores of available data provide a useful point of departure for development of LQIs, although it must be emphasized that no single agency has yet put these data together into an organized database directly suitable for development of LQIs.

Some of the more useful data already collated are described briefly below. These are arranged according to the PSR framework, i.e., the usefulness of these data to develop Pressure indicators, State indicators, or Response indicators.

Pressure LQIs - Available databases and procedures for development

Pressure LQIs can be developed in most cases using available statistical (census) databases. For projects financed by the World Bank, the most useful databases are:

a. ***The World Bank Economic and Social (BESD) Database***[1]: The BESD database contains about 2 million time series in 40 data files from the World Bank, IMF, UN, UNIDO, UNESCO, FAO, OECD, and ILO (World Bank, 1993). It is maintained by the International Economics Division, in collaboration with data users and compilers throughout the Bank. For LQIs, the most useful data files are FAOPROD, FAOFERT, and some of the "Social Indicators for Development" (SOCIND) related to agricultural labour. These are typical statistical (commodity data obtained from agricultural census) data files, obtained on a regular basis from the FAO statistical office. They consist primarily of national production of agricultural commodities (crops, animals, area, yield), inputs (use of fertilizers and other inputs) and cultivation (land use, area harvested, irrigation). Continual time series data are available from 1961. These data can be used to develop broad-level, national indicators such as ratios of:

; cultivated area/arable land
; production/arable land (yield)
; soil conserving/soil degrading crops
; nutrient inputs/nutrient exports.

Indicators such as these identify potential pressures on the land due to agricultural activities (Pressure LQIs). Although targets and thresholds for these indicators are not yet available, trend lines of performance provide very useful information for estimating changes of impact over time.

b. ***World Resources Institute 1994-95 Database:*** This is a PC-compatible database consisting of 503 variables for 198 countries. It is the source database for WRI's publication on global conditions and trends (WRI/UNEP/UNDP, 1994). In some aspects the database is similar to the BESD database in that it contains some of the same variables from the same sources, e.g., FAOPROD, but the data are processed further and often summarized as ratios, and this generally makes the data more useful as indicators. The database provides economic, population, natural resource and environmental statistics as one-time data and 5-, 20-, 30-, and 40-year time series for many of the variables. The most useful data files for LQIs are Land Cover and

[1] The Economic Research Service (ERS)-USDA has prepared a global database called "World Trade: Trends and Indicators, 1970-91", which they update periodically. They have aggregated data from USDA, FAO, World Bank, IMF, UN and country publications, and processed them as time trends. However, most of the database is on economic and trade indicators, and the only indicators related to land are crop land, area harvested and yield. There is no comparative advantage to using this database compared to the BESD.

Settlements, Food and Agriculture, Forests and Rangelands, Biodiversity, Water, and Atmosphere and Climate.

c. ***UNEP/GEMS/GRID Database:*** The Global Environmental Monitoring System (GEMS) is operated by UNEP in collaboration with UN organizations, national governments, environmental groups and scientific bodies. GEMS does not generate new data, but rather accepts data from other national and international agencies, such as FAO, and then harmonizes and pre-processes the data to make them compatible and more accessible and useful to users. Through the Global Resource Information Data Base (GRID), GEMS maintains a variety of global and regional environmental databases, including data on soil, vegetation, climate and cultivation that are useful for LQIs. GEMS receives and stores environmental indicators based on remote sensing data, such as the weekly and seasonal vegetation indices from NOAA and NASA, and the cultivation intensity index from the Goddard Institute for Space Studies. These indices provide useful information on the extent of land cover and the hazards of soil erosion.

Conclusions on Pressure LQIs:

; The World Bank BESD database provides the most useful set of data for development of Pressure LQIs, but this database is not sufficiently comprehensive and must be supplemented by data from the WRI and GEMS databases.

; Although these databases are global, the origin of the data is national and sometimes regional, and therefore can be disaggregated and applied for national and regional projects. Some Pressure LQIs have national meaning, but many have regional significance and these should be geo-referenced using GIS.

; A standard set of these indicators could be selected for reporting in the World Development Reports produced by the World Bank. Over time, these would evolve as international standards, similar to the economic and social indicators routinely reported by the World Bank and others.

State LQIs - Available databases and procedures for development

Whereas Pressure LQIs can be developed using available databases, the situation is not as straightforward for State LQIs. Some national and global computerized databases are being developed, and the most useful of these for State LQIs are described briefly below. In most cases, however, the data remain dispersed among individual, specialized data banks. Also, these data will have to be supplemented with data from other sources, such as long-term experiments and by estimates obtained from physical process models, remote sensing and related techniques. The most useful of these for State LQIs are also described below.

Global and Regional Databases for State LQIs

i. *FAO Databases:* In addition to the statistical data described above, FAO also maintains a collection of soil and agro-ecological databases, some of which originate solely from FAO, and some jointly between FAO and other international institutions, such as IIASA, UNEP and ISRIC. The most useful databases for LQIs include the following:

Agro-ecological Zones Data Bank: This is a global database with data on soils, climate, landforms and some land use. It consists of 500 000 records with a time-span from 1969-1990. Also, the database is linked to a generalized crop growth model which is used to estimate "constraint-free yields" (crop yield based on genetic coefficients of the crop, photosynthetically active radiation, temperature, length of the growing season), and "anticipated yield" (constraint-free yield adjusted by soil limitations such as soil water, salinity, acidification, erosion) for economically important crops. In practice, "constraint-free yield" is not a useful indicator (LQI), except as a theoretical maximum for experimental purposes. However, "anticipated yields" provide useful targets of agronomically and economically feasible yields (providing that these estimates are interpreted as estimates only), and can be compared with current farm yields to develop an LQI such as actual (farm) yield.

Anticipated (potential) yield: As this LQI approaches (or exceeds) 1.0, this indicates increasingly intensive land management, signalling the need to check for possible water quality problems and excessive fertilization. On the other hand, values < 0.2 indicate marginal or submarginal performance of the crop in that area. This could be due to low levels of fertilization (possible nutrient mining), a potentially serious degradation problem, or an unsuitable crop for the region.

CDROM Soil Map of the World: This is a soil database consisting of the digitized version of the Soil Map of the World (1:5M), and various soil interpretations. Georeferenced soil profiles (descriptions and analytical data) are stored in the FAO/ISRIC Soil Database. It is estimated that FAO currently maintains records for about 175 soil profiles.

ii. *ISRIC Databases*:

SOTER: This database consists of attribute files for soil-terrain maps for selected countries mostly in Latin America, the Near East and East Africa, produced in ISRIC-FAO-UNEP collaboration. The information is available at scales of 1:1M or smaller, although larger scales are available in some countries. The SOTER databases are being expanded as the technology is used in different regions.

GLASOD: This global database consists of the digitized map of human-induced land degradation (1:10M), produced by ISRIC with the support of UNEP. It provides estimates of the kind, degree and extent of degradation in all countries of the world. The map and data are based on estimated evaluations of degradation (rather than measured values) provided by local scientists in each country and have been criticized because of this by the soil science community. Nonetheless, it provides the only global estimates of land degradation available, and it will continue to be used until better information becomes available.

WISE: This combined database consists of soil data available from FAO, NRCS and ISRIC. This combined store contains 4 353 soil profiles (Africa - 1 799; South, West, North Asia - 522; China, India, Philippines -553; Australia, Pacific Islands - 122; Europe - 492; N. America - 226; S. America and Caribbean - 599). These profile data are complemented with a simplified grid cell (half degree) database of the World Soil Map.

iii. *World Soil Resources Database:* This database is maintained by the Natural Resource Conservation Service-USDA (formerly the Soil Conservation Service), and it consists of a series of global, national and regional, digitized soil maps (ARC/Info and GRASS) at various scales, as well as special files on soil pedons (profiles), soil carbon and soil climate. The soil pedon database consists of about 17 000 complete records, of which 2 437 are geo-referenced (345 from Central and South America, 179 from Asia and South Pacific, 422 from Europe, 43 from North America (excluding the USA), and 1 386 from other regions). The soil carbon database is built on pedons selected from the soil pedon file, and consists of 2 120 pedons of which 743 are outside the USA. This file is useful for studies on carbon sequestration and organic matter management in relation to climate change. The soil climate file is developed through a procedure which accesses a global climate database of over 27 000 stations, the FAO soil database of the world, and the soil pedon file. Through this interaction, the following information can be generated:

; soil temperature and moisture regimes;
; length and dates of growing season;
; moisture and temperature stress;
; moisture and temperature calendars;
; the FAO soil classification.

Currently, the spatial data files (digitized maps) are minimal, consisting only of 26 maps, all outside the USA, although there is a continental soil map of Africa (1:5M) and a digitized world soil map (1:30M), both derived from an earlier version of the Soil Map of the World. The store of digitized maps, however, is continually increasing.

iv. *Databases maintained by CGIAR Centres*: These are research-oriented databases, maintained by several of the Centres in support of their regional and global research mandates. The data holdings in some of the Centres are quite extensive, particularly in CIAT and ICRAF, but continental or global coverage of any theme is rare (this is normal in research-oriented organizations, since most of the data files originate from project activities). These holdings are summarized as follows:

CIAT: The most complete coverage is climate information for all the tropics (19 000 stations), and topographic elevations. Soil data are minimal, including only the FAO Soil Map of the World for Latin America and Africa. Additional coverages include roads and legally protected areas (Latin America), vegetation (South America), land systems (lowland tropics, Latin America), administrative boundaries (Latin America and Africa) and additional coverages such as population densities (Africa), tribal boundaries (Africa), etc., which originated from the Africa cassava study. Many of the coverages are stored in 10 arc-minute format, and results are produced as digital elevation models (DEMs). CIAT was a pioneer in GIS systems in the CGIAR, and has a large, well functioning installation, operating with ARC/Info and IDRISI software.

ICRAF: This is a new and smaller installation, but similar to that of CIAT in terms of capability and capacity. Most data holdings are for continental Africa. The most complete coverage so far is for climate data, consisting of actual and estimated mean monthly data, as well as daily data (8 000 stations, with 17 year time series). Climate coefficients were obtained from CIAT, Centre for Resources and Environmental Studies (CRES) (Australia) and several national climatic agencies. Soils data are sketchy, but digitized soil maps are available for seven countries (1:1M). Other data, such as vegetation, land cover, etc. are incomplete. DEMs, obtained from the Earth Resource Observation System (EROS) Data Centre, are available for all of Africa. The ICRAF system is still in a rapid stage of development, and data holdings are expected to increase rapidly over the next few years.

ICRISAT: The ICRISAT data holdings include long-term daily climate data for seven countries in Africa, two in Asia and one in South America. Some detailed soil pedon data are available for six countries in Africa and one in Asia. Data from detailed village studies are available for three countries in Africa and for India, and field productivity data are available for India and six countries in Africa. It is not clear if these data are maintained in a GIS format.

Long-term Agronomic Experiments

The Rockefeller Foundation has recently completed a global inventory of continual long-term agronomic experiments as a source of research information for issues related to agricultural sustainability (Steiner and Herdt, 1993). The records include ten experiments from Africa (from 1912), 24 experiments from Asia (from 1909), and nine from Central and South America (from 1941). The types of data, and often the quality, are varied as would be expected, but often include agronomic data, soil characteristics, physiology, weather and economic data. These data would be a valuable source of supporting information for development of LQIs.

Use of Physical Process Models

The overall scarcity of information for development of State LQIs requires the use of indirect measures, and some of the best of these are physical process models. There are many models available in soil science, but most have been developed primarily for research and cannot be easily applied for operational programmes such as LQIs. However, there is a growing family of models which have been verified in many environments, including the tropics to some extent, and are beginning to have a good track record. The most relevant of these for LQIs are described below.

i. *Erosion Productivity Impact Calculator (EPIC):* EPIC was developed by the United States Department of Agriculture (USDA) and Agricultural Research Service (ARS) originally as a tool to analyse the impacts of soil management and erosion on crop yields, but more recently it has been expanded to include assessments of water quality, pesticides, etc. EPIC consists of ten major subroutines, namely, weather, hydrology, wind and water erosion, nitrogen and phosphorus transformations, soil temperature, crop growth, tillage, plant environment control (irrigation, lime, etc.), pesticide routines and economic crop budgets. Interim and final output is available from each subroutine, either in daily, monthly or annual increments. Although the model inputs are flexible through the use of many data defaults (for missing data), the model requires reliable data on soil properties, crop inputs and tillage management (weather is generated through a weather generator). EPIC generates several potentially useful outputs for LQIs, namely:

- yield, for several economically important crops;
- erosion, wind and water, rate (t/ha) and impacts on yield;
- change in nitrogen and phosphorus (crude estimate).

Rates of change are calculated by running EPIC using various land management scenarios over many years (usually 30 years). Increasingly, EPIC is being adapted to many temperate as well as tropical regions as a tool to evaluate land management practices, particularly tillage and residue management. It also has been integrated with large economic optimizing models to provide analytical systems for evaluation of environmental impact prior to implementation of agricultural policies and programmes.

ii. *CENTURY:* The CENTURY model simulates the effects of erosion on long-term storage of soil organic carbon under field conditions. Briefly, soil organic matter is divided into pools with active (1.5y), slow (25y) and passive (1 000y) turnover rates. A plant production subroutine simulates the allocation of carbon into shoots and roots, dividing plant residue into a metabolic (0.1-1y) and a structural (1-5y) pool based on the lignin:nitrogen ratio. The model then transfers the carbon to the soil, and simulates carbon stability through interactions with clay and organic molecules. Estimates of soil carbon change are obtained by running CENTURY under initial (usually current) conditions, then again for future scenarios under new management technologies. Output useful for LQIs include:

- total soil carbon, used to estimate carbon sequestration;
- rapid turn-over fraction, a surrogate for microbial biomass

In terms of land quality, rapid turn-over of carbon is a better LQI than total carbon.

iii. *NUTMON:* This is a recently developed model for estimating regional losses or gains of nutrients as a consequence of nutrient inputs (mineral fertilizers, organic manures, wet and dry deposition, nitrogen fixation, sedimentation), compared to nutrient losses (harvested product, crop residue removal, leaching, erosion, denitrification) (Smaling, 1993). Data for nutrient inputs and nutrients removed by harvest are gathered for various land use systems, and estimates for the other variables are calculated using various available models. NUTBAL then calculates whether the systems are gaining or losing for each macronutrient. Results can be extrapolated to wider areas using GIS techniques. NUTBAL is still experimental, but it has been used for studies in Kenya with good success.

Development of Proxy Indicators

Proxy indicators of State LQIs need to be developed where more reliable information from other sources is not available. Some proxies, such as the Normalized Difference Vegetation Index, can be obtained from remote sensing, or through analyses of aerial photographs. Also, various proxy indicators are available from known cause-effect relationships, such as:

- completeness of vegetative ground cover, proxy for erosion risk hazard;
- sediment load in water bodies, proxy for water erosion;
- removal of crop residues, proxy for nutrient removal and for soil carbon sequestration;
- price of fuelwood, proxy for rate of harvesting of woody materials;

; presence of indicator plants, usually weeds;
; increase in salinity or acidification.

Conclusions on State LQIs:

; There are currently few global and regional databases that can be used for State LQIs, because historically little effort has been expended nationally and internationally to document how land is being used (except for North America and parts of Europe).

; Considerable knowledge is available, however, on cause-effect relationships between land use and change in land quality (pressure-state relationships), and this knowledge has been captured in physical process models of various kinds. Some of the better tested models can be used to develop estimates of State LQIs, but application of the models requires development of large, reliable input files (normally soil data, land management information including tillage, and long-term daily weather data), as well as technological expertise to run the models, verify the output, and interpret the results.

; Proxy State LQIs can be developed using techniques such as remote sensing, aerial photo interpretation and field identification of indicator plants, etc.

; In most cases, State LQIs are location specific and should be geo-referenced at appropriate scales using GIS techniques.

Available Data and Procedures for Development of Response LQIs

Response LQIs primarily involve adoption of soil conservation. This concerns both awareness of the conservation problem and knowledge of what to do about it, as well as adoption of specific conservation technologies by farmers. Response LQIs are distinguished by those promoted by governments, those supported by agri-business, and those undertaken by individual farmers. Response LQIs reflecting government actions are normally national (sometimes regional) in scale, whereas adoption of conservation technologies by farmers is local or regional.

Information Sources for National Response LQIs

Response LQIs can be developed by collating and evaluating the activities undertaken by governments, the private sector, NGOs and farmers in response to problems of soil degradation. Governments normally respond with programmes to increase public awareness, incentive programmes for adoption of conservation practices, improved advisory services, and, in rare instances, legislation. Many of these activities may be undertaken through partnerships among governments, the private sector and NGOs.

Information on these initiatives is readily available from government departments and from the records of private NGOs, chemical and machinery companies, etc. Also, much useful information on these activities can be gleaned from the numerous Participatory Rural Appraisal studies completed through Bank-financed studies, NGOs and others. This information can be used to develop Response LQIs such as:

; kind, duration, funding of awareness and incentive programmes;
; kind, duration, funding of incentives programme;
; legislation for conservation;
; activities, size, membership of conservation associations;
; etc.

The presence and impact of farmer self-help groups for soil conservation, such as conservation clubs and "Club de Terra", can be powerful Response LQIs. If these associations are strong and active, this indicates that farmers are aware of the degradation problems and are prepared to make investments to overcome them (normally an incentive programme is necessary to get them started, and to assist with the investment costs). Farmer conservation clubs and associations should not be confused with farmer marketing cooperatives, however. In some cases the marketing coops may also promote activities in soil conservation, but often they focus only on marketing and may actually be counterproductive.

Information on Adoption of Soil Conservation Technologies

The adoption of improved technologies in soil conservation by farmers is an important statistic for development of LQIs, yet this is never available and must be gathered. Through programmes such as the agricultural census (the full census or special surveys), or it can be instituted as part of the project activities (rapid project surveys). Whatever procedure is chosen, a special land management questionnaire has to be developed to gather the relevant data. The questionnaire must be strategically designed, short and cost effective to implement if it is to be used (an example is given in Appendix 1). With such data, Response LQIs could be developed such as:

; use of conservation structures, % farmers, extent;
; use of conservation tillage, % farmers, extent;
; use of special inputs (manures, lime, etc.);
; integration with livestock, agroforestry;
; participation in soil conservation associations;
; etc.

These could be summarized as national Response LQIs, or they could be summarized for specific regions covered by a project. Response LQIs based on average adoption rates are useful, but they have to be correlated with the specific biophysical or production constraints prevailing in an area, eg. absence of techniques for control of wind erosion in a high wind erosion risk area may indicate lack of awareness of the problem. Caution must be exercised to ensure that average national conditions do not mask important local variability, e.g., an individual farm may be sustainable because of superior management, in an area that is judged overall to be experiencing major problems, and vice-versa.

Major shifts in land use, sometimes called indicators of unsustainability (Jodha, 1990), are also useful Response LQIs. These shifts occur when the performance of one land use has deteriorated beyond an acceptable threshold and survival depends on adopting some alternative, often less intensive system. Such response LQIs may be:

; retirement of marginal lands;
; shift from cultivation to pasture;
; shift from cattle to goats;
; abandoned terraces;
; increased seasonal migration;

At the other end of the scale, major shifts in land use can also occur due to new market opportunities or some major change in resource availability. In all cases, Response LQIs must be interpreted on the basis of knowledge on the motivation(s) for the response.

GUIDELINES FOR APPLYING THE PSR FRAMEWORK

Some general guidelines have been developed for using the PSR framework with LQIs. The pressure and response indicators are generally considered at the level of the *agricultural sector* (agriculture in this case, but may also be forestry or other biological land uses), whereas the state indicators relate directly to *change in condition and in some cases the quantity of the land resource*. Changes in state, even if they are of small magnitude such as oxidation of organic matter or nutrient balance, can be of considerable impact if they occur over large areas.

Sectoral pressures and response are useful for expressing the impacts of the sector on the condition of the land, and therefore often relate directly to the policy arena. Indicators that can show relationships between pressures and change in state generally have the most meaning for environmental decision makers.

The application of the PSR approach to LQIs requires that *key land issues* be identified for each cluster of indicators, i.e., what are the key policy-related questions on land that must be answered? These should be developed carefully, since they are crucial for identifying the short list of strategic indicators and sub-indicators to be associated with each issue and each cluster. Normally, these issues are associated with specific geographic regions, and reflect the priorities of these regions. Local farmer knowledge and the advice of experienced agronomists can be very useful in this portion of the exercise.

Targets or goals for each indicator should then be developed if possible (Adriaanse, 1993), as well as *thresholds* where the systems may become unsustainable (Smyth and Dumanski, 1994). Performance of the sector can then be monitored in relation to these targets, goals and thresholds, i.e., the contribution of the sector to resource maintenance or resource degradation can be assessed. If realistic, reliable and scientifically sound targets and thresholds cannot be developed, however, then trends in performance can still provide very useful information.

The pressure-state-response framework has been used for state-of-the-environment reporting and for national environmental performance reviews. For the LQIs, it is used to structure and classify information, and to assist in the identification of the key set of indicators that best describe how farmers are managing their lands and the impacts of this management.

The PSR framework remains in a continuous state of evolution. The EPA (1994) is proposing to extend the framework to include the effects of changes in state on the environment (pressure-state-response/effects). UNEP (1994) is discussing the development of pressure-state-impact-response (PSIR) framework. O'Connor (1994a) has extended the PSR framework towards development of a "sustainability matrix". In a recent development, EPA (1994) is proposing to re-orient environmental reporting more towards "place-driven" approaches, using ecosystem stratification, spatially referenced data, and geographic information systems.

MAJOR PROGRAMME ACTIVITIES AND METHODOLOGY FOR THE LQI PROGRAMME

The LQI programme is targeted to specific objectives, outputs and beneficiaries. The intent of the programme is cost-effective development and validation of harmonized indicators that reflect a broad consensus. Activities and programmes already under way will be included to avoid duplication of effort and resources. Activities related to the LQIs, such as those currently under way in FAO, UNEP, UNDP, OECD, the CGIAR, and several of the international scientific unions such as SCOPE and International Council of Scientific Unions (ICSU), will be used.

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APPENDIX 1

DEVELOPMENT OF A SOIL CONSERVATION MODULE FOR ADOPTION OF CONSERVATION TECHNOLOGIES

The adoption of soil conservation technologies is an important source of information for developing LQIs, but these data are almost never available. Procedures must therefore, be developed to collate these data either through national census, special project studies, or research. Adoption of soil conservation technologies provides information on how farmers are managing their land, and this is necessary to develop good Response LQIs and to enable proper interpretation of Pressure and State LQIs.

Soil conservation technologies are the foundation for attaining sustainable land management, i.e., maintenance of soil quality must first be assured if other interventions and investments are to be effective. Also, many of these technologies have been tested in many parts of the world, and much is known about changes in soil quality with adoption of conservation.

Adoption of soil conservation technologies by a farmer is never done in isolation, but as part of a larger farm management strategy. Therefore, a variety of data is required in addition to information on adoption. The complete information required includes the following:

; size, distribution and tenure of farm;

; crops grown, area and yield;

; integration with livestock and/or agroforestry;

; crop and livestock management and inputs;

; soil conservation and tillage practices.

These data are essential for development of Response LQIs, but also for input to models and other procedures for State LQIs.

Part of these data is already being gathered in many standard census, questionnaires, but some are additional to the normal census. The following section outlines how part of the information requirements can be integrated with existing census data forms, and then proposes a new module to be added for soil conservation.

The example shown is generic, and it is more complete than would be necessary for many countries. Also, it would have to be carefully tailored to the land-use systems prevailing in the country of application to be useful. Although the questionnaire appears to be quite long, most responses are multiple choice, thereby making the questionnaire easy to implement in the field and effective for computerized data analyses.

TABLE 1

Example of a questionnaire for adoption of conservation practices

The first set of questions (or something similar) usually standard on most census questionnaires

1 Size, distribution and tenure of farm

What is the total area of your farm ____u.a[1]

What is the total area owned ____u.a

What is the total area leased, rented or sharecropped:

from governments or tribal authorities ____u.a

under Islamic law ____u.a

from others ____u.a

Has the number of fields on your farm changed over the last five years

Increased ____ Decreased ____

---

2 Crops grown, area and yields (?)

On your farm, do you usually grow:

one crop per growing season _____

more than one crop per growing season _____

both, depending on the field _____

If you grow more than one crop per growing season, which of the following do you use: _____

relay cropping _____

intercropping _____

strip cropping _____

other (please specify)

Report the total area of crops grown (seeded or to be seeded) on your farm:

Maize: for grain area ____u.a yield ____u.a

for silage area ____u.a yield ____u.a

Wheat: spring area ____u.a yield ____u.a

winter area ____u.a yield ____u.a

---

3 What draught power do you usually use for cultivating your fields:

hand labour _____

animal power owned _____

hired _____

Do you use a tractor to cultivate your fields

no ____ yes____

small tractor (<30hp) owned _____

hired _____

large tractor (>30)hp owned _____

hired _____

---

4 Do you irrigate any portion of your farm

no ____ yes____ area ____

gravity or flood _____

centre pivot _____

portable _____

linear _____

trickle _____

drip _____

microjet _____

---

[1] Please specify the unit area used (e.g, ha).

The second set of questions would be added to the census questionnaire

1 Integration with livestock and/or agroforestry

Do you keep animals on your farm:

no ____ yes: ____

- **cattle, sheep or goats** ____
- **chickens, turkeys, etc** ____
- **horses, mules, etc** ____
- **camels** ____
- **other (specify)** ____

Are trees important for your farm:

no ____ yes: ____

- **fruit, nuts** ____
- **fuelwood** ____
- **building materials** ____
- **poles, stakes** ____
- **windbreaks** ____
- **shade** ____
- **other (specify)** ____

2 Crop and livestock management and inputs

What was the area of land on which each of the following was used:

- **commercial fertilizer** ____u.a
- **manure** ____u.a
- **mulches or compost** ____u.a
- **herbicides** ____u.a
- **insecticides or fungicides** ____u.a
- **field drainage** ____u.a

On your farm, do you use any

local fertilizers such as rock phosphate, etc.

no ____ yes ____

lime

no ____ yes ____

crop varieties tolerant to acid soils

no ____ yes ____

special procedures to control soil salinity (alkali)

no ____ yes ____

3 Soil conservation and tillage practices

Is soil erosion a problem on your farm

no ____ yes ____

If yes, which of the following practices do you use to control soil erosion:

- **none** ____
- **crop rotations using cultivated grasses, legumes, etc.** ____
- **cover crops** ____
- **cultivation along the contour** ____
- **strip-cropping along the contour** ____
- **mechanized terraces** ____
- **biological terraces (with barrier crops)** ____
- **grassed waterways** ____
- **windbreaks or shelterbelts** ____
- **stone lines** ____
- **other (please specify)** ____

Which of the following implements do you use to prepare your land for seeding
- traditional farm plough
- hand hoe/rake _____
- land leveller _____
- mouldboard plough _____
- disk harrow _____
- spike harrow _____
- spike cultivator (plough) _____
- rotary tiller _____
- other (please specify) _____

_____

What area of land is prepared for seeding using
- convention tillage (most of the residues are incorporated into the soil) _____u.a.
- conservation tillage (most of the crop residue (trash) is retained on the soil surface) _____u.a.
- no tillage (seed placed directly into stubble or sod with a special planter) _____u.a.

4 Soil conservation associations/programmes

Do you know of any soil management and conservation associations in your area:

no ____ yes____

Are you a member of any of these associations:

no ____ yes____

Are any incentive programmes for soil conservation available in your area:

no ____ yes____
- government _____
- NGO _____
- private companies _____

Do you participate in any of these incentive programmes:

no ____ yes____

Land condition change indicators for sustainable land resource management

Land resources **management** is the actual practice of the use(s) of the land by the local human population, which should be sustainable (FAO/Netherlands, 1991). In a broader sense it includes land-use planning, as agreed between stakeholders; legal, administrative and institutional execution; demarcation on the ground; inspection and control of adherence to the decisions; solving of land tenure issues; settling of water rights; issuing of concessions for plant and animal extraction (timber, fuelwood, charcoal and peat, non-wood products, hunting); promotion of the role of women and [other] disadvantaged groups in agriculture and rural development in the area; and the safeguarding of traditional rights of indigenous peoples (FAO, 1995).

Improved land management that ensures better resource use and promotes long-term sustainability is basic to future food production and to the economic welfare of rural communities. Because of the dynamic aspects of land management, a flexible and adaptive "process" approach for monitoring the quality and quantity of the world's land resources (such as soil, water, plant nutrients) and for determining how human activities affect these resources is essential. However, the systematic assessment of sustainability of current or planned land uses can be hampered by too many detailed data that are difficult to interpret, lack of baseline information from which to compare change, or data that are inconsistent over time or over geographic area (USDA, 1994).

Many researchers are trying to define **sustainability indicators** and to devise methods to monitor them in field conditions (FAO, 1995). There is not yet a sufficiently clear description and explanation of the features of sustainability indicators and of their limitations or weaknesses that may generate inconsistencies, create confusion, or lead to misinterpretation. Since one element of sustainability is to understand change (or impact), in either direction (degradation or improvement), this paper uses the term "**change indicators**" instead of sustainability indicators or land quality indicators. Indicators of change are needed to guide land users in their decisions on the management of their land and water resources and inputs.

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MAJOR ISSUES OF LAND MANAGEMENT

From the land management point of view, the major concerns are:

- decline in quality of soils as rooting environments;
- erosion and loss of topsoil by wind and water;
- loss of vegetation cover, including woody perennials;
- acidification, soil fertility decline and plant nutrient depletion;
- salinity and salinization, particularly in irrigated systems.

> **BOX 1**
> **Common features of a land degradation problem**
>
> **It is commonly asserted that erosion and runoff are caused by 'deforestation', 'overgrazing' and 'over-cultivation'. This has led to many attempts to prevent rural people from doing such things, which has generally proved unpopular and unsuccessful. However, there are other more effective ways to limit erosion problems, within production systems and prevent the loss of: (a) soil cover; (b) organic matter in the soil; (c) spaces in the soil architecture, which may be overcome and recuperated by improved systems of management of the crop-soil complex (Shaxson, 1995).**

While many of these processes are natural, their impacts are aggravated by inappropriate management systems and human-induced pressures. The effect of this is to reduce the productive potential of the land, and to reduce its capacity to serve as a natural filter or resilient buffer for other land uses. The common features of a land degradation problem are shown in Box 1.

LAND QUALITIES AND LAND QUALITY INDICATORS

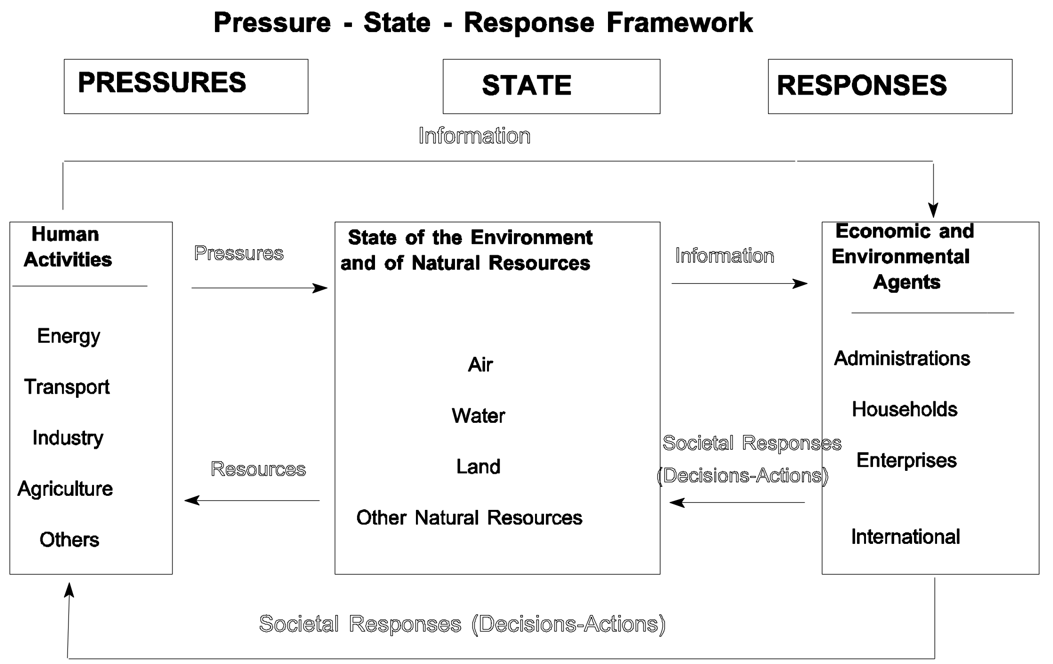
Land qualities as used by FAO for many years in the context of land evaluation (FAO, 1976) are complex attributes (for example, nutrient availability) that affect the suitability of the land for a specified use in a distinct way. Land qualities can also be defined in negative terms, as "land limitations" (FAO, 1995). Illustrative listings of potentially relevant land qualities are given in the paper *Land Resources Evaluation and the Role of Land-related Indicators.*

Indicators are used increasingly to provide convenient descriptions of current state or condition of a resource, as well as to gauge performance and predict responses. Indicators are statistics or measures that relate to a condition, change of quality, or change in state. A distinction must be made between indicators and other types of statistics as shown in Box 2.

> **BOX 2**
> **Distinction between indicators and other types of statistics**
>
> **Measurement of some event or phenomenon produces raw data, which after processing are often published as statistics. These statistics can provide underlying information, or they could be indicators if they have a specified significance and are tied to some specific application. If the number of indicators is reduced by aggregating them according to some formula, then these aggregated ones are called indices.**

While land quality describes the combined state of soil, water and vegetation cover for each unit of land, land quality indicators (LQIs) are needed to reflect the land's capacity to support biological systems for specific human uses (Hamblin, 1994).

FIGURE 1
Pressure-state-response framework



The World Bank (Pieri *et al.* 1995) conceptual basis for the development of LQIs is a generic assessment of soil/land "health" under a **pressure-state-response** framework shown in Figure 1.

Under this framework, *Pressure* (the causative factors) refers to the driving forces exerted on land by human activities and their impact on the status of land quality; the effects of an expanding or diminishing animal population, for example in a game park; environmental changes unrelated to terrestrial factors, such as the sun spot cycle. *State* characterizes the type, degree, spatial extent and rate of change of vegetation, soils, nutrients and water - comparable to the GLASOD assessment (paper on *Global and Regional Databases for Development of State Land Quality Indicators: the SOTER and GLASOD Approach*). *Response* characterizes the conscious efforts by land users and governments to remedy any degradational change. Sets of selected indicators identified

BOX 3
ISSUE: RESOURCE AVAILABILITY

- ***Pressure Indicators***
  - *productivity of arable land*
  - *increased use of marginal lands*
  - *increased cropping intensity*
- ***State Indicators***
  - *change in erosion*
  - *change in productivity (yield/ha)*
  - *change in water quality*
- ***Response Indicators***
  - *change in out-migration*
  - *shift to more tolerant crops*
  - *change in rate of land abandonment*
  - *change in capital investment*
  - *change in input use efficiency*
  - *change in production systems*
  - *any positive response action by government/institutions*

during a recent international workshop (World Bank/ ICRAF, 1994) for resource availability and for soil management strategies are shown in Boxes 3 and 4, respectively.

Three clusters of LQIs have been developed to reflect the pressure-state-response structure as shown in Box 5. A wide range of statistics is collected by FAO on demographic, financial, economic and production aspects that are useful to derive LQI clusters 1 and 3.

BOX 4
ISSUE: SOIL MANAGEMENT STRATEGIES

- ***Pressure Indicators***
  - *technologies imported from other dissimilar environments*
  - *technologies unrelated to range of natural variability/risk*
- ***State Indicators***
  - *gaining/declining in nutrient status*
  - *gaining/declining in organic matter*
  - *gaining/declining in yield per unit area or yield per unit input*
  - *increased/reduced in wind and/or water erosion*
  - *increased/reduced in runoff/storm event*
  - *increased/reduced in acidification*
  - *increased/reduced in variability*
- ***Response Indicators***
  - *increased use of manure and residues*
  - *change to more tolerant crops, or to crop to livestock mix*
  - *expansion of cultivated area/farm*
  - *increase in abandoned/degraded land*
  - *formation of farmer support groups/ conservation clubs*
  - *subsidies*

LAND CHANGE INDICATORS

In each situation, there will be a different range of land factors for which changes could be observed, and from which indicators of change could be derived. Not everything that happens can or should be monitored. Land change indicators must be representative of or indicative of, or a proxy for, the factor considered important (such as production potential). Complex changes may be highlighted by choosing a limited number of suitable indicators which are regularly monitored and compared with previous readings back to the baseline for each one. Special studies might then be undertaken to characterize more of the details, for instance in concrete rural and agricultural development projects.

BOX 5
CLUSTERS OF LQIs

Cluster 1: Pressure (or driving force)
Estimates of the intensity of production, as well as the range of production systems used, number and types of products and the complexity of systems used such as area of crop, pasture or grazing land; potentially arable and pasture lands; proportion of monoculture/mixed farming, etc.

Cluster 2: State (or condition)
Measurements that express current quality of the land, as well as estimates of future land quality as reflected through land management practices such as estimates of actual to potential biological productivity; extent and severity of major soil constraints; etc.

Cluster 3: Response (from society)
a) Automatic effect of the changes, if no positive response from society is made.
b) Measures employed through policies and programmes to create awareness of the problem, improve land management technologies, and counter or ameliorate the impacts of land degradation such as the number and kinds of soil conservation awareness and education programmes; special credit programmes for soil conservation; etc.

To measure changes, it is essential that the baseline conditions are established at the very outset for people's attitudes (both farmers and advisory staff), for socio-economic conditions, and for biophysical conditions.

To determine nature of changes, direction of changes and rates of change, assessments need to be done on a recurring basis and compared with baseline data. Land managers therefore require ***land change indicators*** to monitor and evaluate *what* is changing, the *processes* by which change is occurring, and the *sustainability* of beneficial changes.

With carefully chosen key indicators, which may be direct or proxy, the work involved in monitoring the change is kept to a minimum. It is important that those making the measurements and observations make unbiased reports based on them, without favouring one interpretation or another - that is done during evaluations made from time to time. Both farmers and researchers need to be involved in monitoring and subsequent evaluations.

In the framework of an integrated, holistic approach to land-use decisions and management, the changes in important biophysical and socio-economic attributes of land units must be monitored, especially in matters such as:

- rates of adaptation and adoption of recommended or suggested practices;
- changes in areas under different land uses;
- changes in farm management practices;
- changes in yields and other outputs as a result of, as well as independently of, project interventions;
- changes in the condition of land resources, both positive and negative.

SELECTION AND ANALYSIS OF LAND CHANGE INDICATORS

Selection

Once it has been decided which of the many possible specific indicators will be measured, the baseline condition for each ***change indicator*** (if not already available) should be defined at once before too much change has taken place. After each round of monitoring, the results are compared with the baseline condition, differences (if any) are analysed, trends identified, feedback provided to project management, and any necessary supplementary surveys initiated to provide further insights or explanations of what has been observed (based on Casley and Kumar, 1987; 1988; Lai, 1991 and UNESCO, 1984).

Criteria for selecting key land change indicators: data collection for monitoring should be pragmatic. The standards of data accuracy and reliability should not be as demanding for a management information system as for experimental studies and academic research. Other considerations, such as timeliness, relevance and cost-effectiveness, are more important.

Criteria for effective indicators, appropriate to what managers need to know, include:

- unambiguous definition;
- consistency and objective measurement, no matter who measures;
- specificity;
- sensitivity to changes in project situation, to reveal short-term movements rather than those with a long time-lag;
- ease of collection, within the capacities of the available team.

Types of data: two types of data will be needed in monitoring land changes in rural situations:

; Quantitative data: "How much?"; "How quickly?"; "What size and shape of area?" etc.
; Qualitative data: "What?"; "How?"; "When?"; "Why/why not?"; "Who?"; "Where?"

Qualitative data (including that provided by farmers themselves) may suggest aspects that it may be important to monitor quantitatively - as for instance changes in soil conditions.

Avoiding bias: in monitoring qualitative information it is important not to ask "loaded" questions which increase the likelihood of the questioner getting the answer he/she wishes to hear, for example: "How have these soil conservation measures been useful?", which tells the farmer what is the answer you are hoping for! Men, women and youths may each have significantly different perceptions and views of their surroundings and situations. Unexpected comments which do not conform with a questioner's own assumptions and preconceptions should not be discarded, as they may constitute important keys to understanding of significant alternative viewpoints.

Nature and scale of change: for understanding the *nature* of changes taking place, detailed information is probably best achieved from observations and records from single farms. For the *scale* of overall project effects to be determined, one also needs to find out over what area and on what percentage of farms similar results are to be found.

Rate of change: economic and social effects of project activities are ultimately the most significant, and probably the most quickly perceived, particularly by farm-family members, even within the space of one year. Significant changes in natural resource conditions following changes in people's decisions about how to use them are likely to become evident more slowly, probably over several years, for example: changes in forest cover; changes in soil structural conditions; changes in total produce output from an area.

Objectivity: to be as objective as possible, to the extent possible, the null hypothesis should be kept in mind: it is assumed at the outset that **no** change has occurred as a result of project effort unless there is sufficient evidence to the contrary. Qualitative information can be used to frame provocative statements and questions of the form, for example: "These physical conservation works must take a lot of land out of production and be a nuisance - what was the reason for installing them?" Such obviously biased statements may provoke a true response from farmers.

Zoning: unless the whole area is very homogeneous there may be a need to zone it beforehand for various reasons. One reason is that different indicators are appropriate for different zones, that accurate results can only be achieved by *separating out* the different zones or different development programmes, land uses, or treatments that might be appropriate in each zone, etc. Zoning *sensu strictu* is a delineation of areas of rural lands that could be earmarked for one or another use or non-use, based on identical physico-biotic conditions and prevailing socio-economic infrastructure. The resulting units can be denominated as resource management domains (RMDs), i.e., areas within a broad physico-biotic zone that have similar socio-economic conditions; (FAO, 1995). The FAO agro-ecological zoning framework provides a regionalization scheme of particular relevance for the identification of key land change indicators. Tentative lists of LQIs for arid, semi-arid and sub-humid regions of Africa (World Bank/ICRAF, 1994) and LQIs for steeplands and acid savannahs areas of Latin America (World Bank/CIAT, 1994) are shown in Appendixes 1 and 2.

Multi-disciplinarity and inter-disciplinarity: a multi- and inter-disciplinary approach to assessing and analysing monitored information is essential, particularly because:

; both natural resource conditions and relationships between people and their surroundings are complex and dynamic;

; the same reality will be viewed differently by persons of different disciplines, including rural people themselves as intended beneficiaries;

; persons from social science and geographic disciplines have much to contribute at both planning and implementation stages of monitoring of projects concerned with natural resources and with the people who use them.

Special studies: special studies may be needed, following feedback of specific information, in order to examine a problem in depth, provide background to particular attitudes, determine whether an unexpected problem is caused by project actions, etc. They will be designed in order to answer specific questions at particular points in time, and thus differ from recurrent recording of the same indicators as undertaken in monitoring itself.

Analysis of change

It is not enough to monitor progress towards attainment of pre-determined project goals, nor merely to record end results. It is also important to understand the processes involved in producing the observed effects, both socio-economic as well as agro-ecologic. For this, it is necessary to monitor factors within a geographical area which can be influenced or managed by the rural communities (such as resources of land, labour, capital, their attitudes and management skills) but also those factors outside their farms and outside their control (such as weather conditions, market conditions, policies and legislation, availability of technical support, infrastructure provision, population pressures on land, etc.) so as to be able to judge the effects of these vis-à-vis project actions in affecting farmers' opinions, decisions and reactions.

Analysis of land change data will involve both *place-to-place* comparisons (e.g., between resource management domains at a given time), *time-to-time* comparisons (e.g., changes in land use in a particular resource management domain over a given period) and - if possible -*with-and-without project* situations (e.g., comparisons between apparently equivalent farms within as well as outside the resource management domains).

For time-to-time comparisons, the same individuals, groups, farms or sites must be used on each occasion, to provide directly comparable time-series of data.

For with-and without comparisons (areas with project assistance vs. those representing unaffected situations), the same questions should be asked, the same indicators used, with individuals, groups, farms or sites as similar as possible in both situations except for their exposure to project actions.

Frequency of change monitoring:

; This will vary according to the type change. It may be more than once a year: (inherent characteristic of the farming or land-use system, for example: labour requirements for different seasonal tasks; availability of water in river or borehole in each month; changes in percentage ground-cover as a crop matures);
; once a year (e.g., yield of particular crop on the farm plot);
; every 2-3 years (e.g., development of local institutions);
; miscellaneous timings (e.g., adhoc observations may suggest a need to monitor a particular factor not yet specified).

Outputs of land change monitoring

Reports to higher authority are the primary output of a land change monitoring exercise. These may be routine monitoring activities or in-depth studies for particular purposes. It is important however that the information contained in them is interpreted accurately and 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 labelled tables;
; integrating similar materials from various parts of the information system;
; assembling the results over time by geographical area, so that trends and inter-area comparisons become apparent;
; ensuring that the analysed and interpreted material is credible and, if unexpected or unusual, backed by specific supporting evidence;
; preparing brief, concise and clear narrative material which is timely and designed for the specific target audience.

Valuable data may be rendered useless if they are not analysed and presented in a relevant form. On the other hand, an excess of analysis using statistical techniques misapplied to data that do not meet quality requirements may result in presentation of results with spurious reliability and coefficients that the user does not understand (Casley and Kumar, 1987).

PRACTICAL APPLICATION OF LAND CHANGE INDICATORS: CASE OF COSTA RICA

FAO is developing and has applied a pioneering methodology designed to change concepts concerning soil erosion and conservation to fit better the wide range of complex situations encountered in small-farm agriculture of the steeplands of Costa Rica. There, sustainability depends primarily on the maintenance and improvement of soil conditions, plus the satisfaction of farm families which leads to them wanting to stay on the land because their lives are becoming more secure and satisfying.

One main change in the project's soil conservation approach is from considering farmers as part of the problem, to recognizing them as part of the solution. In this regard, farmers' comments on changed characteristics and qualities of their soils are important signals, and give a complementary, pragmatic and integrated impression of what may be measurable, for example: porosity; soil-structure stability; water-holding capacity; colour; pH; total and plant-available nutrient content; organic-C content; and worm count (see Box 6).

Changes in water quantity, time-distribution, evenness of flow, quantities of runoff and turbidity with eroded soil materials are likely to be noted by farmers, and can be measured and compared with baseline conditions.

> **BOX 6**
>
> ***FARMERS' INDICATORS OF THE EFFECTS OF BETTER HUSBANDRY***
>
> **Farmers used indigenous indicators for determining the reduction in soil erosion. Some of the indicators included: soil becoming softer over the years; plants growing more uniformly; changing colour of soils from dull brown to darker colours; contour walls becoming smoother without slumping during the rainy season; land strips on the contour farm becoming flatter; water flowing out of field and water in nearby creeks are fairly clear in contrast to muddy conditions in the past; stones or gravel on the soil not visible any more; decreased frequency of landslides and contour wall slumps; sticky soils becoming more friable, thereby absorbing much of rainwater, thereby reducing the speed of rain water flow on the surface; increase in the depth of top soils on the farm; less and less soil deposits in contour canals, soil traps and checkdams. The soil getting darker, softer, water going in more easily, and the carabao [water-buffalo] does not get so tired when ploughing, (Buktan *et al*, 1994).**

The project set up a provisional list of land change indicators for the purpose of the assessment of project progress and impact on the state of land, sustainability of results, autonomous spread of project-initiated ideas, background factors and change in output and income (Shaxson, 1995).

The project also compiled a list on the *State of Land Conditions* as they relate both to conditions on the farms and to those outside the farms but within the group's allocated area or catchment (see Table 1).

Sustainability: a most important aspect of sustainability, besides stability of the soil, is whether people wish to stay on their farms using and refining the improvements they have made with the project's assistance (see Table 2).

Autonomous spread of project-initiated ideas: a good idea will spread on its own without need for massive expansion of the extension service. There are two main indications of effectiveness: (a) the **adaptation** by farmers of one or more original ideas or techniques introduced by the project, so as to fit each particular situation; (b) information about successful improvements being spread by farmer-to-farmer contacts (see Table 3).

Background factors: certain background conditions require monitoring to provide possible bases for explaining some of the changes and variations observed within pilot areas. Weather conditions affect crop yields and farm profitabilities. Changes in policies, etc. alter farmers' frame of reference within which decisions are made (see Table 4).

Changes in output and income: considerable amounts of detail can be derived from the socio-economic surveys (see Table 5).

CONCLUSIONS

The indicators are many and often difficult to estimate or measure precisely. More work is needed at country level to determine some of these parameters. The indicators to be developed should be of primary use by (sub)national policy-makers and international funding agencies for integrated land resources planning and management (Chapter 10 Agenda 21). Development of field projects may be one effective method of improving the estimation or measurement of land quality indicators, as in the case of the soil conservation project in Costa Rica.

TABLE 1
State and changes of land conditions

Question / Factor ('past' below, refers to a year that should be specified)	Indicator/Measurement	Monitoring Interval
State of soil characteristics: observed changes from past	; Farmers' comments and indicators	Any
	; Colour (Munsell colour chart)	
; organic matter content	; Laboratory analyses	2 years
	; Infiltration rate measurements	
; structure/porosity conditions	; Pore-space analysis	2 years
	; Photos	
; water-holding capacity	; Farmers' indicators, comments on plant responses in drought	2 years
	; Laboratory: pF curves	2 years
; ease of tillage	; Farmers' comments on time taken for tillage/ha.; tiredness of animals after tillage	1 year
	; Dynamometer readings	1 year
; reduced erodibility	; Farmers' indicators; their comments re intense rainstorms' effects on soil losses	1 year
; soil biological activity	; Transects: no. of worm-casts /metre	1 year (before harvest)
State of the productive potential of the land, and comparison with past	; Farmers' comments, observations, indicators	Any
; efficiency of plant production	; Kg. fertilizer per kg. output	1 year
	; Area sq. metres per unit output of given crop	1 year
; pest and disease occurrence	; Farmers' observations, indicators	2 weeks
	; Pest counts, transects	2 weeks
	; Expenditures on pesticides etc.	1 year
	; Farmers' comments, observations, indicators	1 month +
Occurrence and severity of runoff and erosion; and comparison with past	; Frequency of need to re-seed, re-plant, re-apply fertilizer	Any
; loss of inputs etc.	; Photos	Any
	; Measurements from fixed points	1 year
; rate of increase in gullies' size	; Point-transects - lines	2 weeks
	; Quadrats - areas	2 weeks
; reduced erosivity / crop cover	; Overhead photos	2 weeks
State of water supplies and comparison with past	; Women's comments re streams' and boreholes' reliability in dry months	6 months
; amounts	; Measurements of yield, stream flow	2 months
	; Women's comments	Any
; quality	; Laboratory analyses	4 months
Protection of reserved areas, state and comparison with past	; extent of area under native vegetation protected by group	1 year

TABLE 2
Sustainability

Question / Factor	Indicators/Measurement	Monitoring Interval
Is there evidence of people preferring to stay on the farms rather than take other work?		
; unwillingness to sell land	; Per-hectare value of land (a) per individual farmer (b) in general Pilot Area	1 year
; investment of own funds in water-supply system	; Household	1 year
; investment in soil improvement	; Number of heaps of manure and/or compost, per ha	1 year, pre-planting
; tree planting	; Number of well-kept spontaneous tree nurseries	6 months
	; Number of trees planted+surviving	1 year
; non-essential investments in house and garden	; Ornamental trees, garden layout, etc; kitchen gardens established	1 year
; autonomous development of common-interest groups	; Number of groups ; Diversity of interests	1 year
Is there continuity of interest in project suggestions?		
; size of each farming group	; Numbers attending	Each meeting
; constancy of individuals' membership	; List of names attending	Each meeting
; acknowledged usefulness of group	; Members' comments	1 year
; shared investments	; Individuals' own money into jointly-owned equipment or buildings, etc.	Any
Do the field staff feel a sense of interest and commitment?	; Recorded attitudes and comments of Regional and Agency staff	Any

TABLE 3
Autonomous spread

Question / Factor	Indicator/Measurement	Monitoring Interval
Are farmers adopting favourable technologies?	; No. of farmers in group adopting a suggested new technology without modification	1 year
	; No. of farmers experimenting with and adapting a suggested new technology before implementing as an on-farm routine	6 months
	; No. of 'farmers-collaborators' adapting and implementing more than one improved technology in their own farming systems	1 year
	; No. of farmers wanting to repeat own trials of a particular technology for more than one year	6 months
Is there continuity of interest from year to year?	; No. of farmers taught a new technology by farmers in original groups, within Pilot Areas	1 year
Is there any spread outwards from original farmers?	; No. of farmers taught 'second-hand' by those themselves taught by farmers in original groups	Any
	; No. of unexpected requests for project assistance in starting new groups within or outside 'recommendation domains' of original Pilot Areas	

TABLE 4
Background factors

Question / Factor	Indicator	Monitoring Interval
What have been the climatic conditions?	; Daily rainfall, as close to farm sites as possible (even on-farm, simple raingauges)	Daily, analysed 3 months
	; Other weather parameters, particularly temperatures, relative humidity, wind.	Monthly, analysed 1 year
How have costs and prices varied?	; Trends at local markets, input stores, traders	Monthly, analysed 1 year
Have there been changes in policies, legislation, and/or institutional arrangements?	; Note as they occur	Any

TABLE 5
Changes in output and income

Question / Factor	Indicator/Measurement	Monitoring Interval
Main indicators		
Has total output per farm risen?	; Farmers' comments ; Farmers' records	1 year
Has total output for the area risen?	; Cooperatives' and local traders' records	2-3 years
Has output become less variable year-to-year?	; Comparisons of above	1 year
Has food security per household increased?	; Volume of storage per household ; Dietary variety: number of crops grown for on-farm consumption	1 year 1 year
Has the yield of each crop on the farm risen?	; Farmers' records ; Crop-cutting + weighing of output from small plots	1 year Up to 1 year
Has the diversity of crops on farm increased?	; Hectares under each crop type	1 year
Has the proportion of the farm needed to satisfy subsistence needs reduced?	; Hectares under subsistence crops	1 year
Has mixed farming developed?	; Types and numbers of animals	
Other indicators		
Is crop-plants' development quicker and more profuse?	; Crop height (relative to height/age/yield curves) ; Crop cover (relative to cover/yield relations) ; Frequency of necessary weeding	2 weeks 2 weeks
Has plant density of crops and pastures increased?	; Count plants/unit length (line transect)	3-6 months
And others as indicated by farmers	; and others as indicated by farmers	As appropriate

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APPENDIX 1

SUMMARY OF INDICATORS DEVELOPED DURING NAIROBI WORKSHOP 1994

Arid Lands - Mainly Grazing with Opportunity Cropping

All possible indicators considered:

; Livestock pressure: diversity (90 species)
; Livestock: people ratio
; Boom-bust (climatic cycle) duration
; Mobility patterns (degree of mobility)

Short-return indicators for grazing lands (within a year):

; Number of different livestock
; Condition of animals (skins, ticks, seeing ribs on animals)
; Ratio of livestock:people (high = less pressure; low = high pressure)
; Meat prices or markets

Long-term (>2-5 years)

Vegetation:

; Density
; Land cover changes
; Proportion of bare land and loss of trees
; Proportion of palatable species
; Species shift

Soil indicators

; Thickness of wind-borne deposits
; Loss of top soil
; Salt encrustation
; Gullies and rills
; Chlorosis

Cropland indicators

Deterioration of cropland:

; Progression (shift) of cropland areas as land deteriorates
; Number of weed species on fallow lands
; Condition of crop
; Presence of certain weed species (e.g., striga)
; Change of surface soil colour from dark to pale

Semi-Arid Lands - Broad Categories of Issues

1. Mismatch between Resource Availability and Management:

   - Resource Availability:
     ; Declining arable land per caput
     ; Water supply
     ; Fuelwood (on-farm and household energy)
     ; Level of investment (on-farm)
     ; Off-farm income
     ; Biophysical variability and risk

   - Resource Management:
     ; Declining soil fertility
     ; Runoff and erosion
     ; Inadequate soil and crop management
     ; Ratio of actual to potential land use/productivity
     ; Risk management strategy, e.g., crop and animal diversity

2. Policy Environment:

   ; Marketing
   ; Land-use policy and land tenure
   ; Policies towards cash crops
   ; Alternative support systems

3. Infrastructure:

   ; Input availability and supplies
   ; Education and training
   ; Research and development
   ; Communication

4. Awareness:

   ; Extension services (outreach and efficiency)
   ; Local farmer knowledge

5. Research Priorities:

   - Main emphasis should be on reliable data

   - Develop methods to increase usefulness of available data:
     ; Census
     ; Project
     ; Benchmark sites

   - Increase reliability of national census, timeliness and data quantity:
     ; Special census

- Include small module for on-farm land management in the national census to collect necessary data.

- All future data collection efforts should take advantage of modern, emerging, information technologies.

Subhumid Lands

Intensity - Diversity of land-use

Prop. of cultivated land:

; Veg. cover - biomass, diversity and key species
; Carrying capacity - FAO method using different population density levels of technology
; Livestock density
; Upgrading - degrading land (ratio)
; Crop and livestock diversity index
; Diversity of land-use system compared with suitability

Land quality

; Erosion factor - from USLE
; Carbon balances (input-output models)
; Farm nutrient balances
; Water quality and quantity for drinking - silt load downstream, stream flow

Soil fertility

Responses:

; Government policies on land
; Levels of poverty
; Health and nutrition status of household
; Production - actual yield to target yield
; Access to resources:
  - information
  - natural
  - economic
; Management - economic productivity of land
; Value of land and the market
; Equatability
; Types of access:
  - farmer organizations
  - markets
  - barter
  - social network
  - extension
; Economic diversity of sources of wealth:
  - level of market integration
  - credit, schools

APPENDIX 2

SUMMARY OF INDICATORS DEVELOPED DURING CALI WORKSHOP 1994

Land Quality Indicators for Acid Savannahs

PRESSURE: Issue is *Intensity of Land Use/Agrodiversity*

Proportion of land-use types
Stability of net farm profits

Issue is *Impact of Agriculture on the Environment/Biodiversity*

Proportion of land-use types
Proportion gallery forests, wetland, savannahs
Land management practices

STATE: Issue is *Soil and Water Quality*

Nutrient balance, fertilizer, lime
Water table
Land management practices
Ratio actual:potential productivity
Weed community
Sediment load
Water contamination
Percent soil cover

Issue is *Productivity*

Nutrient balance, fertilizer, lime
Net farm profits
Trends in crop yields
Ratio actual:potential productivity

RESPONSE: Issue is *Awareness*

Adoption of conservation measures
Impacts of new technologies

Land Quality Indicators for Hillsides

PRESSURE: Issue is *Impacts of Human Activities*

Human population density
Age-sex ratios
Access to natural resources

Access to markets and services
Issue is *Intensity of Land Use and Management*
Agrodiversity by farm
Agrodiversity by region
Major land-use types

STATE:

Issue is *Soil Quality*

Soil fertility index
Vegetative cover on the land

Issue is *Water Quality*

Availability domestic, industrial, irrigation
(on-site and off-site)
Water quality
(on-site and off-site)

Issue is *Biodiversity*
Natural habitat (extent and fragmentation)
Species variation

RESPONSE: Issue is *Awareness*

Adoption of conservation farming practices by area

Session 2

Sectoral issues in developing indicators

Global and regional databases for development of state land quality indicators: the SOTER and GLASOD approach

Since its establishment in 1966, the International Soil Reference and Information Centre (ISRIC), under its mandate:

> *"to collect and disseminate scientific knowledge about soils for the purpose of a better understanding of their formation, characterization, classification, distribution, and capability for sustained land utilization at local, national and global scales",*

prepared a number of national, continental and global soil profile databases and spatially georeferenced soil and terrain databases for a wide range of applications and users (Batjes *et al*., 1994).

These databases are known under the following acronyms:

ISIS: ISRIC Soil Information System
WISE: World Inventory of Soil Emission Potentials
SOTER: World Soils and Terrain Digital Database

Within the framework of the United Nations Environment Programme (UNEP) and in close cooperation with the Food and Agriculture Organization of the United Nations (FAO), ISRIC has coordinated the development of a database on global soil degradation status and is presently preparing a regional database on soil degradation status for South and Southeast Asia:

GLASOD (Global Assessment of the Status of Human-induced Soil Degradation)
ASSOD (Regional Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia).

These databases can be used as a baseline for the development of Land Quality State Indicators. The preamble for a series of workshops (1992) initiated by the World Resources Institute and the California Institute of Technology (Global Environmental Monitoring: Pathways to Responsible Planetary Management) states:

> *"In order to manage our planet's environment rationally, we must understand Earth* system processes, obtain a measure of the baseline conditions of Earth Resources,

L.R. Oldeman, International Soil Reference and Information Centre (ISRIC), Wageningen, Netherlands

TABLE 1
Database status of reference profiles stored in ISIS (December 1994)

Country	ISIS	Archive	Country	ISIS	Archive
Australia	3	36	Mali	8	1
Belgium		4	Mozambique	9	
Botswana	7		Namibia	3	6
Brazil	28	1	New Zealand		5
Cameroon	1		Nicaragua	11	
Canada		21	Nigeria	28	
China	51		Norway	2	1
Colombia	18	1	Oman	4	
Costa Rica	12		Pakistan	6	
Côte d'Ivoire	7		Peru	21	
Cuba	22		Poland	14	8
Czech Republic		8	Philippines	6	
Denmark		8	Romania	11	
Ecuador	20		Rwanda	10	
Finland		5	South Africa	12	9
France	11	1	Spain	19	
Gabon	6		Sri Lanka	4	
Germany	14	3	Sweden	5	14
Ghana	1	5	Switzerland		1
Greece	15		Syria		4
Greenland	1		Thailand	13	
Hungary	3	16	Turkey	16	
India	12	18	United Kingdom		11
Indonesia	46		Uruguay	10	
Ireland	3	7	USA	4	21
Italy	17		former USSR	2	60
Jamaica	4		Venezuela	1	
Japan	4		West Samoa	5	
Kenya	68	3	Yugoslavia		3
Malaysia	18		Zambia	11	
Malawi	1		Zimbabwe	13	
			Total (1994)	652	296
			total (1992)	*375*	*440*

TABLE 2
Global pedon database

Broad geographic region	WISE	No. of profiles in homogenized database (Int. set) derived from WISE database			
		FAO	NRCS	ISIS	Total
Africa	1799	93	204	18	315
South, West and Northern Asia	522	24	44	0	68
China, India, Indonesia, Philippines	553	45	129	106	280
Australia and Pacific Islands	122	28	27	0	55
Europe	492	5	2	0	7
North America	266	14	144	0	158
Latin America + Caribbean	599	41	114	86	241
	4353	250	664	210	1124

and monitor and report on changes in Earth resources and environmental quality. *The SOTER activity of UNEP, FAO and ISRIC plans to use properly structured ground assessments to create a baseline geo-referenced database on soils, soil degradation, and terrain over the next 10-15 years if funds become available. These data would be invaluable to local, and national planners and to those seeking to set priorities for global action and environmental assistance".*

Benites (1995) states that a systematic assessment of sustainability of current and planned land uses is hampered by 1) too many detailed data that are difficult to interpret; 2) no baseline from which to compare change, and 3) data that are inconsistent over time or between geographic areas. In the following section a brief overview is given of the baseline databases prepared or coordinated by ISRIC, in close cooperation with FAO, UNEP, the International Society of Soil Science (ISSS), and national natural resources institutions worldwide.

BASELINE DATA ON SOILS, TERRAIN AND SOIL DEGRADATION STATUS

ISIS

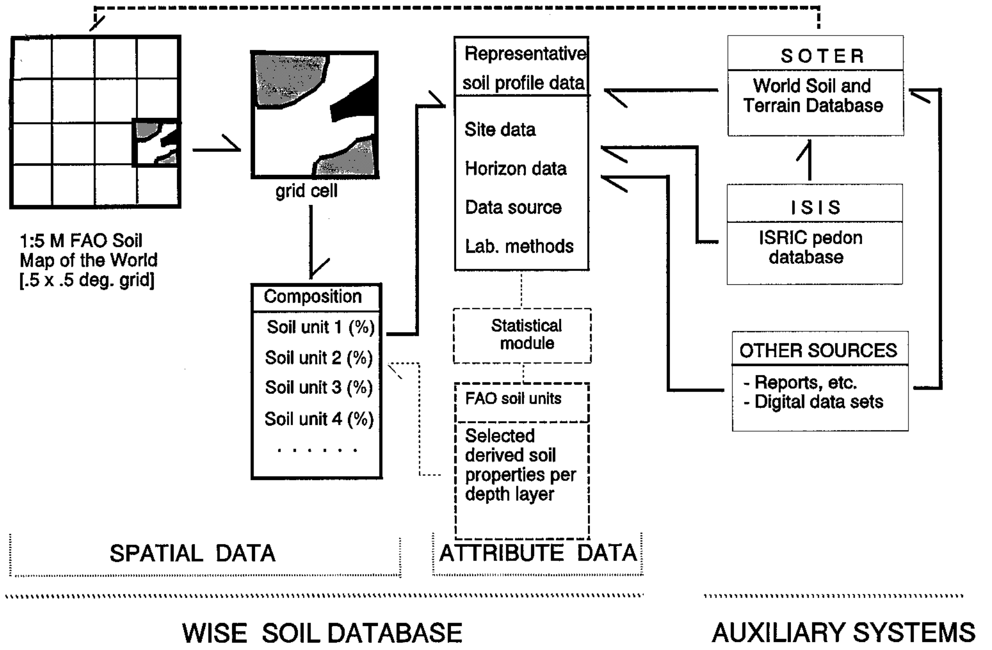
Since ISRIC's establishment in 1966 as an International Soil Museum, soil profiles have been assembled, standard analytical procedures developed, soil samples analysed and associated information collected to illustrate the units of the FAO-UNESCO Soil Map of the World. To facilitate the storage and management of the soil and environmental data collected and analysed, a computerized database management system was developed (ISIS), which has been operational since 1986 (Van Waveren and Bos, 1988). Out of a total of some 950 reference profiles around 650 are now stored in ISIS (Table 1). It is envisaged that by 1997 the ISIS database will be completed. The uniqueness of this database is that all stored information on soil attributes is analysed in a standardized way. The dissemination of the information in ISIS is in the form of hard-copy Country Reports, while selections of the database can be requested in electronic format. Appendix 1 gives an example of the stored information.

WISE

A global soils database, linked through a GIS to the only viable global soil map available (the FAO-UNESCO Soil Map of the World), is now available in digital format with errors corrected and boundary changes included. This database (Table 2) is composed of international datasets held by the Natural Resources Conservation Service (NRCS) of the USA, by FAO, and by ISRIC (i.e. ISIS) and complemented with regional and national databases where and when available. Also included are resources of the ISRIC library collection. Software is available to (mechanically) transfer data held by the major data holders from one database to another. Currently the WISE database contains 4353 profiles (Africa - 1799; South, West, North Asia - 522; China, India, Philippines - 553; Australia and Pacific Islands - 122; Europe - 492; N. America - 266; S. America + Caribbean - 599).

The cartographic database of WISE has been built up mechanically, by identifying soil associations occurring in each 5'x5' grid-cell of the digital version of the World Soil Map, computing the percentage area of each soil unit present in the 36 cells which make up the ½°x½° grid-cell (Nachtergaele, unpublished data, 1994) using FAO's standard composition rules, and aggregation of information to generate soil geographic area data relevant to each terrestrial ½°x½° grid-cell. Each of these grid-cells consists of up to ten different soil units (Figure 1, Batjes and Bridges, 1994).

FIGURE 1
Schematic representation of the WISE database



SOTER

The World Soils and Terrain Digital Database (SOTER) programme provides an orderly arrangement of natural resource data in such a way that these data can be readily accessed, combined and analysed from the point of view of potential use, in relation to food requirements, environmental impact and conservation. Basic in the SOTER approach is the mapping of areas with a distinctive, often repetitive pattern of land form, surface form, slope, parent material and soils. Each area is linked to a geographic information system with a database containing available attributes on topography, land form and terrain, soils, climate, vegetation and land use. In this way each type of information or each combination of attributes can be displayed as a separate layer or overlay or in tabular form.

SOTER is an initiative of the ISSS and the approach was adopted at the 13th World Congress of Soil Science in 1986. The SOTER methodology was developed with UNDP support and in close cooperation with the Land Resources Research Centre of Canada, FAO, and ISSS. After initial testing in three areas, involving five countries (Argentina, Brazil, Uruguay, USA, Canada) the methodology was endorsed by the ISSS Working Group on World Soils and Terrain Digital Database, further refined and in 1993 the Procedures Manual for Global and National Soils and Terrain Digital Databases was jointly published by UNEP, ISSS, FAO and ISRIC, thus obtaining international recognition. The procedures manual is available in English, French, and Spanish.

The SOTER concept was developed for application at a 1:1M scale. However, the methodology can be used at different levels of spatial aggregation. At larger scales subdivisions into smaller sub-units will be necessary (cf. De Oliveira and Van den Berg, 1992). At smaller scales, reduction of the number of attributes is proposed.

In 1992 an international panel to evaluate SOTER was convened by UNEP. The panel recommended not only SOTER activities at national level using scales ranging from 1:500 000 to 1:1M, but also the development of small-scale continental SOTER databases. In 1993 a joint action plan was formulated and jointly financed by UNEP, FAO, and ISRIC to compile a 1:5M SOTER database for Latin America. The SOTER approach applied at scale 1:5M is seen by FAO, UNEP and ISRIC as the formal strategy to replace the Soil Map of the World in the near future (in 2002 at the latest).

The following SOTER databases are completed or currently under construction:

Scale 1:5 million:

; Argentina, Brazil (partly), Cuba, Ecuador, Mexico, Uruguay, Venezuela: completed;
; all other Latin American countries: under construction;
; Russia, China and Mongolia, in the framework of the land use and cover change activities of IIASA (under construction);
; South and Southeast Asia, as follow-up of the ASSOD activities (under discussion).

Scale 1:1 million:

; Argentina (16%), Uruguay, Kenya: completed;
; Syria, Jordan: under construction.

Scale 1:500 000:

; Hungary: completed.

Scale 1:100 000:

; Pilot areas in Argentina, Uruguay: completed.

The SOTER methodology is also being used in Bolivia, Ethiopia, Europe, USA and in North Asia outside the direct involvement of ISRIC. SOTER project proposals have been submitted for funding for China, for Central and Eastern Europe, and for high mountain areas under the Consultative Group on International Agricultural Research (CGIAR) Initiative for Global Sustainable Mountain Development. For further information on the SOTER methodology reference is made to Van Engelen and Wen (1995) and Appendix 2.

GLASOD

In view of UNEP's need for a scientifically credible global assessment of the status of human-induced soil degradation, ISRIC was requested to prepare, in cooperation with over 250 soil scientists worldwide, a world map of the status of human-induced soil degradation at scale 1:15M at the equator (Mercator projection). Regional cooperators were asked to delineate on a standard topographic basemap (derived from the world map of the Institut Geographique National) map units showing a certain homogeneity of physiography, climate, vegetation, geology, soils and land use. Within each delineated map unit, soil degradation types were identified and interpreted for the degree of degradation, their relative extent within the unit and for the type of human intervention that has resulted in soil degradation during the post-war period. The regional results were then generalized and compiled as world map.

As a follow-up activity the GLASOD map was digitized and through a GIS linked to a soil degradation database with attributes derived from its legend. Single value maps on various types of soil degradation and its severity were prepared by UNEP for inclusion in the World Atlas of Desertification. The tabular statistics on extent, degree and causative factors have attracted worldwide attention and were published in the World Resources Report 1992-1993 of the World Resources Institute (WRI, 1992) and were used in IFPRI's 2020 Vision papers (Yadav and Scherr, 1995). Although GLASOD data are based on qualitative expert estimates and provide only a first approximation of the worldwide status of soil degradation, the GLASOD study is according to IFPRI *"one of the most cited studies in recent literature on the extent of global soil degradation"*. More details on GLASOD can be found in Oldeman (1994) and Appendix 3.

At the request of the Steering Committee for the conservation and management of the environment and natural habitats of the Council of Europe an updated version of the European section of GLASOD was prepared (Van Lynden, 1995b).

ASSOD

The third meeting of the Expert Consultation of the Asian Network on Problem Soils (October, 1993) was devoted to the collection and analysis of land degradation data. The consultation recommended to adopt the GLASOD methodology and recognized the need to adopt a physiographic approach in conformity with the SOTER methodology in order to develop national and regional geo-referenced databases to be utilized not only in monitoring soil degradation status but also in estimating key sustainable development factors (FAO, 1994). Under an agreement with FAO a physiographic map and database at 1:5M scale was prepared. The guidelines for soil degradation status assessment were adapted and in late 1994 UNEP supported an Assessment of the status of human-induced soil degradation in South and Southeast Asia, implemented by ISRIC in coordination with national institutions in 16 participating countries and FAO. In ASSOD more emphasis is placed on the assessment of the degree of soil degradation (Van Lynden, 1995a).

Table 3 illustrates how national institutions are asked to derive the degree of soil degradation from the impact on productivity (increase or decrease) in combination with the level of management inputs (e.g., if there is no increase in production despite a major level of management improvements the area is considered to have a moderate degree of soil degradation). During an expert consultation in Manila (November, 1995) ASSOD members expressed the need to prepare more detailed national assessments, to develop a 1:5M SOTER database for the region, and national SOTER databases at larger scales.

THE STATE OF LAND QUALITIES

The databases described in the previous sections form the baseline conditions for the identification of the present or near-present conditions of the land. They can be used to estimate land qualities such as moisture availability, nutrient availability, erosion hazard, flooding hazard, available foothold for roots, conditions for germination, conditions for mechanization, availability of oxygen for root growth, excess of salts, soil toxicities.

TABLE 3
Impact of soil degradation on productivity

Level of production increase/decrease	Level of Input/Management improvements		
	A) Major	B) Minor	C) Tradition
1) Large increase	No significant impacts (stable)	No significant impacts (stable)	No significant impacts (stable)
2) Small increase	Light	No significant impacts (stable)	No significant impacts (stable)
3) No increase	Moderate	Light	No significant impacts (stable)
4) Small decrease	Strong	Moderate	Light
5) Large decrease	Extreme	Strong	Moderate
6) Unproductive	Extreme	Extreme	Strong to Extreme

In a pressure-state-response framework baseline information on land conditions is a prerequisite. This will indicate the "inherent", biotic, chemical and physical conditions of the land. These conditions are influenced by outside pressures, which are the normal pressures exerted by natural (climatic) events or those exerted by human activities, depending on the type of land use and land management. As a result the state of the land conditions may change in a negative or positive sense. If the natural resource base is sufficiently stable (or is stabilized) and the pressure exerted on the conditions is balanced by land management inputs, the state of the land conditions may not change at all (sustained utilization of the land). The impact of these changes may lead to a response to halt further degradation or to rehabilitate the degraded land to its initial conditions. In the absence of any response, further pressure may lead to further deterioration of the land conditions, eventually leading to a situation in which the land has lost its productive capacity.

At ISRIC several procedures have been developed to determine the state of the conditions of the land. An ISIS-based procedure has been developed for a qualitative evaluation of the land conditions. This procedure (with acronym STRESS, Mantel and Kauffman, 1995) uses the Automated Land Evaluation System (ALES). It indicates the potential physical suitability of reference soils for low input, arable farming and lists their major limitations, thus enabling the comparison of soils from different parts of the world.

A SOTER-based, automated procedure for qualitative land evaluation is developed (created in ALES). This procedure (acronym SOTAL, Mantel, 1995), provides a methodology that allows quick separation of the potentially suitable SOTER units from those not suitable for an intended land use, and lists constraints for different kinds of land use. SOTAL case studies have been executed in Kenya and Uruguay. The procedure is a useful tool in land-use planning, because constraints for different kinds of land use can be determined quickly. Areas indicated as potentially suitable have no major physical limitations for a proposed land use. For more specific statements, for instance on potentially attainable yield, a quantified land evaluation is needed, using dynamic crop growth simulation models. The attractive feature of the procedure following the pathway of a qualitative land evaluation in SOTAL, preceding a quantified land evaluation, is that non-suitable areas can be neglected in the quantified land evaluation, which demands more data and time.

A SOTER-based programme is developed for the assessment of water erosion hazard (Van den Berg and Tempel, 1995). In this programme (acronym SWEAP), two alternative erosion assessment models, based on SLEMSA (Soil Loss Estimation Model for Southern Africa, developed by Elwell and Stocking, 1982) or the Universal Soil Loss Equation (USLE), developed by Wischmeyer and Smith, 1978) can be selected. Modifications were introduced in order to adjust the programme to SOTER's facilities and limitations. The aim of SWEAP was to achieve a balance between refinement of the equations and the available information. Results obtained by using SWEAP are in terms of abstract "erosion hazard units", rather than quantified estimates of potential soil loss. SWEAP has been tested in a SOTER pilot area in Canada, in pilot areas in Uruguay and is now being applied in Kenya within the framework of UNEP's programme, "National land degradation assessment and mapping in Kenya".

The GLASOD and ASSOD activities mentioned above provide a qualitative assessment of the status of soil degradation. The approach used in these studies provides indicators for soil degradation state. The estimated impact on productivity of each type of soil degradation is indicated, as well as the "recent past" rate of degradation over the past five to ten years. Although a change in soil and terrain properties may reflect the occurrence and intensity of soil degradation processes, it does not necessarily reflect the seriousness of their impact on overall soil productivity (removal of a 5 cm layer of topsoil has a greater impact on a poor shallow soil than on a deep fertile soil). It would be better to measure the degree of soil degradation by the relative changes of soil properties: the percentage of the topsoil lost, the percentage of total nutrients and organic matter lost; and the relative decrease in soil moisture holding capacity.

Declining productivity as an indicator for soil degradation can also be hazardous because yield declines may arise from factors such as soil degradation, improper management, drought or waterlogging, quality of inputs, pests and diseases. It is therefore important to consider a medium to long period (10-15 years) to level out large aberrations resulting from fluctuations in weather patterns or pest and disease occurrence. On the other hand, soil degradation can be "hidden" by the effects of management measures such as soil conservation techniques, improved availability of external inputs, increased levels of fertilization, better land management. Part of these inputs is used to compensate for productivity losses caused by soil degradation.

In order to indicate the change in degree of soil degradation over time, a qualitative estimate of the trend of soil degradation is given in ASSOD. It is important to know whether a severely degraded area is stable at present, or whether an area that presently has only a slight degree of degradation may show a trend towards rapid further deterioration. At the same time, the ASSOD map will also indicate areas where the situation is improving (for example through soil conservation measures). In this context the project World Overview of Conservation Approaches and Technologies (WOCAT) is worth mentioning.

CONCLUSIONS

Soil and terrain databases form the basis for the assessment of land qualities. Soil degradation databases provide useful indicators of the conditions of the land. Baseline information on the state land qualities is essential to monitor changes in land conditions over time. It would be worthwhile to resample some profiles represented in ISRIC's soil reference collections to determine changes over time. Most of the sites are well-documented and this provides a unique opportunity to study land condition changes as a result of exerted pressures. Another possibility to compare changes over time would be to compare land conditions between areas under natural cover and areas with similar soils but used for agricultural production. To assess the effect of a relative change of soil properties on food productivity, the potential biological productivity of reference soils can be estimated with and without assumed losses of topsoil, or with removal (mining) of nutrients by crops, with and without fertilizer inputs.

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APPENDIX 1

Reference soil BR 13, BRAZIL — Print date: 25 July 1995

FAO/UNESCO	(1988)	: Alumi-Geric Ferralsol
	(1974)	: Acric Ferralsol
USDA/SCS SOIL TAXONOMY	(1994)	: Very fine, kaolinitic, isohyperthermic Xanthic Hapludox
	(1975)	: Haplic Acrorthox
LOCAL CLASSIFICATION		: Latossolo amarelo distrófico
DIAGNOSTIC CRITERIA	FAO (1988)	: ochric A, ferralic B horizon, geric properties
	USDA/SCS (1994)	: ochric epipedon, oxic horizon Soil moisture regime : udic, bordering to ustic Soil temperature regime : isohyperthermic
		: FAO (1988): geric properties, because ECEC is less than 1.5 $cmol_c$/kg clay. USDA/SCS (1994): no Acrudox, because pH (1*N* KCl) is less than 5.0.

LOCATION		: Para State, highway BR 163 (Santarem-Cuiaba) at km 52.2, near Belterra
	Latitude / Longitude	: 2°54'0"S / 54°56'0"W Altitude : 75 m a.s.l.
AUTHOR(S)		: Kauffman, J.H. & J.S. Martins Date : November 1984

GENERAL LANDFORM		: lacustrine plain, very flat over long distances.		
	Topography	: flat or almost flat		
PHYSIOGRAPHIC UNIT		: flat plain		
SLOPE	Gradient	: 1%	Position of site: flat	
MICRO RELIEF	Kind	: few dispersed small termite mounds at the soil surface		
SURFACE CHAR.	Rock outcrop	: nil	Cracking	: nil
	Stoniness	: nil	Salt	: nil
	Slaking/crusting	: nil	Alkali	: nil
SLOPE PROCESSES	Soil erosion	: slight sheet	Aggradation	: not apparent
	Slope stability	: stable		

PARENT MATERIAL	Type, texture	: lacustrine sediments, clayey
	Remarks	: Belterra clay; geogenesis of the Belterra clay is not very well understood

EFFECTIVE SOIL DEPTH		: >250 cm
WATER TABLE	Kind, depth	: no watertable observed Estimated highest level : 500 cm
DRAINAGE		: well
	Drainage remarks	: no clear surface drainage network present, all surplus precipitation infiltrates to the deeper subsoil and flows laterally through the substratum to the Rio Tapajoz.
PERMEABILITY		: high
FLOODING	Frequency	: nil Run off : medium
MOISTURE CONDITIONS PROFILE		: 0-250 cm moist

LAND USE		: (semi-)natural vegetation
VEGETATION	Type	: evergreen forest
	Land use/vegetation remarks	: forestry research station; in neighbourhood of site limited wood extraction

ADDITIONAL REMARKS:
BIOLOGICAL ACTIVITY: black and red ant activity in the litter layer. REFERENCES: reference soil BR 13 is comparable to soil profile 1 in Boletim de Pesquisa no. 20.

CLIMATE:	Köppen	: Am
MET. STATION	Name, location	: BELTERRA, 2°40'S / 54°53'W, 31 m a.s.l.
		: TAPERINHA (SANTAREM), 2°26'S / 54°43'W, 72 m a.s.l.
	Distance to site (relevance)	: BELTERRA, 15 km N of the site (good); TAPERINHA (SANTAREM), 90 km ENE of the site (moderate)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
BELTERRA														
EP Penman	mm	143	112	141	123	141	139	154	180	186	185	161	157	1821
relative humidity	%	85	92	87	90	80	75	70	59	59	68	78	80	77
precipitation	mm	235	395	325	368	210	182	107	38	30	53	132	190	2265
tot. glob. rad.	MJ/m_2	18.4	16.1	18.3	16.3	18.1	18.4	19.7	22.7	23.9	23.0	20.6	19.7	19.6
T mean	°C	27.3	27.0	27.0	27.2	27.4	27.4	27.6	28.3	28.7	28.9	29.1	28.3	27.8
bright sunshine	h/d	42	31	40	35	49	55	61	71	70	62	51	49	51
TAPERINHA (Santarem)														
EP Frere, Popv	mm	112	97	106	101	99	97	108	125	131	140	127	124	1367
precipitation	mm	273	272	312	342	211	128	65	43	66	111	169	217	2209
est. glob. rad.	MJ/m^2	16.2	15.5	15.2	15.3	15.0	15.6	17.0	19.4	20.0	20.0	19.0	17.8	17.2
T mean	°C	26.2	26.2	26.4	26.2	26.3	26.6	26.8	27.5	27.9	27.8	27.6	26.8	26.9
T max	°C	30.0	29.9	30.0	29.9	30.7	31.1	31.6	32.7	33.1	32.7	32.0	31.1	31.2
T min	°C	23.3	23.2	23.2	23.3	23.6	23.4	23.2	23.5	23.9	24.1	24.0	23.7	23.5
windsprred (at 2m)	m/s	1.1	1.2	1.2	1.0	1.1	1.1	1.1	1.3	1.3	1.2	1.2	1.2	1.2
vapour pressure	mbar	28.5	28.6	28.6	28.9	28.8	28.3	27.6	27.6	28.4	28.8	29.1	29.0	28.6
bright shunshire	%	36	33	30	33	45	58	66	69	62	55	48	40	48

Agroecological zonation (AEZ): TAPERINHA (SANTAREM): wet days 203, intermediate days 68, dry days 94. Type of growing season: normal growing season (with dry period). Season lasts from 7 November to 15 July.

Reference soil BR 13, BRAZIL — Print date: 25 July 1995

PROFILE DESCRIPTION:
Very deep, well drained brownish yellow clay developed in lacustrine deposits; porous massive, strongly acid and very low in nutrient content and retention. The soil layer from 10 to 50 cm has a faint dark greyish mottled appearance. This mottling is caused by humus which is not well homogenized through the soil.

Ah	0 - 7 cm.	Brown (10 YR 5/3, moist) clay; weak to moderate fine to very fine subangular blocky to crumb; sticky, plastic, friable; many very fine and fine pores; common very fine and medium roots; clear smooth boundary to
AB	7 - 25 cm.	Yellowish brown (10 YR 5/4, moist) clay; weak subangular blocky to porous massive; sticky, plastic, friable; many very fine and fine pores; few fine and medium roots; gradual smooth boundary to
BA	25 - 48 cm.	Brownish yellow (10 YR 6/6, moist) clay; weak fine to medium subangular blocky to porous massive; sticky, plastic, firm; very fine and fine pores; few fine and medium roots; diffuse smooth boundary to
Bu1	48 85 cm.	Brownish yellow (10 YR 6/8, clay; weak fine to medium subangular blocky; sticky, plastic, firm; broken thin clay cutans; many very fine and fine pores; few fine and medium roots; diffuse smooth boundary to
Bu2	85 - 170 cm.	Brownish yellow (10 YR 6/8, moist) clay; moderately coherent porous massive; sticky, plastic, firm; broken thin clay cutans; many very fine and fine pores; few fine and medium roots; diffuse smooth boundary to
Auger	170 - 300 cm.	Reddish yellow to brownish yellow (7.5 to 10YR 6/8, moist) clay; moderately coherent porous massive; few fine roots

ANALYTICAL DATA:

PARTICLE SIZE DISTRIBUTION (µm)----------------------------------

Hor.	Top	Bot.	>2 mm	2000 1000	1000 500	500 250	250 100	100 50	TOT SAND	50 20	20 2	TOT SILT	<2	WDIS	BULK DENS	pF- 0.0	--- 1.0	--- 1.5	--- 2.0	--- 2.3	--- 2.7	--- 3.4	--- 4.2	SSA
Ah	0 -	7	-	0	1	5	4	1	11	4	1	4	84	43.9	-	-	-	-	-	-	-	-	-	70
AB	7 -	25	-	0	1	3	2	1	7	5	0	5	88	49.4	1.11	51	47	42	39	39	37	35	33	65
BA	25 -	48	-	0	1	2	1	0	4	4	0	4	92	0.0	1.13	51	47	42	40	39	38	36	34	62
Bu1	48 -	85	-	0	1	1	1	0	4	2	1	4	93	0.0	1.11	48	47	43	40	39	38	36	35	61
Bu2	85 -	130	-	0	1	1	1	0	4	4	1	5	92	0.0	1.19	50	50	48	45	43	42	38	37	61
	130 -	170	-	0	1	2	1	0	4	1	6	6	90	0.0	-	-	-	-	-	-	-	-	-	59
Auger	170 -	250	-	0	1	2	1	0	4	3	3	6	90	0.0	-	-	-	-	-	-	-	-	-	60
	250 -	300	-	0	1	2	1	0	4	4	6	9	87	0.0	-	-	-	-	-	-	-	-	-	59

Hor.	pH H20	pH KCl	CaC03	ORG. MATTER C	N	EXCHANGEABLE BASES Ca	Mg	K	Na	sum	EXCH. H+Al	ACID. Al	CEC soil	CEC clay	CEC OrgC	ECEC	BASE SAT	AL SAT	EC2.5
Ah	3.9	3.7	-	2.6	0.21	1.0	0.3	0.1	0.1	1.5	2.0	2.0	6.9	8	9.2	3.5	22	29	0.26
AB	4.5	3.9	-	1.4	0.10	0.4	0.1	0.0	0.1	0.6	1.5	1.6	5.5	6	4.8	2.1	11	29	0.06
BA	4.6	4.0	-	0.8	0.08	0.2	0.1	0.0	0.1	0.4	1.1	1.3	3.0	3	2.7	1.5	13	43	0.02
Bu1	4.8	4.0	-	0.5	0.08	0.0	0.1	0.0	0.0	0.1	1.0	1.1	2.6	3	1.8	1.1	4	42	0.02
Bu2	5.1	4.1	-	0.4	-	0.2	0.1	0.0	0.1	0.4	0.9	1.0	2.6	3	1.2	1.3	15	38	0.01
	5.4	4.2	-	0.3	-	0.0	0.0	0.0	0.1	0.1	0.8	0.9	1.9	2	0.9	0.9	5	47	0.01
Auger	5.2	4.1	-	0.3	-	0.0	0.1	0.0	0.0	0.1	0.8	0.8	2.1	2	1.1	0.9	5	38	0.01
	5.2	4.2	-	0.2	-	0.0	0.1	0.0	0.1	0.2	-	-	1.9	2	0.8	-	11	-	0.01

ELEMENTAL COMPOSITION OF TOTAL CLAY--

Hor.	Si02	Al203	Fe203	Ca0	Mg0	K20	Na20	Ti02	Mn02	P205	ING. LOSS	Si02/ AL203	Si02/ Fe203	Si02/ R203	Al203/ Fe203
Bu2	42.1	35.8	6.3	0.00	0.00	0.01	0.01	2.00	0.00	0.05	13.7	2.0	17.7	1.8	8.8
	41.8	35.5	6.3	0.00	0.00	0.01	0.03	2.01	0.00	0.05	13.7	2.0	17.6	1.8	8.8

CLAY MINERALOGY (1 = very weak, → 8 very strong) / EXTRACTABLE Fe Al Si Mn (by amm. oxal.(o), Na dth(d) & pyroph.(p)

Hor. no.	MI	VE	CH	SM	KA	HA	ML	QU	FE	GI	GO	HE	Fe(o)	Al(o)	Si(o)	Fe(d)	Al(d)	Fe(p)	Al(p)	P-ret	pHNaF
Ah	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.1	0.0	1.6	0.3	-	-	21	-
AB	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	0.0	1.7	0.3	-	-	20	-
BA	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	0.1	1.8	0.4	-	-	20	-
Bu1	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.1	0.0	1.8	0.3	-	-	22	-
Bu2					6			2			4	4	0.0	0.1	0.1	1.8	0.3	-	-	21	-
					6			2			4	4	0.0	0.1	0.1	1.8	0.4	-	-	-	-
	-	-	-	-	-	-	-	-			-	-	0.0	0.1	0.1	1.6	0.3	-	-	-	-
Auger	-	-	-	-	-	-	-	-			-	-	0.0	0.1	0.1	1.6	0.3	-	-	-	-

Key : KA=kaolinite; QU=quatz; GO=goethite; HE=hematite

SAND MINERALOGY

Hor.	HEAV	LIGH	Light fraction QU	FE	PL	RE	heavy fraction OP	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Bu2	69.7	30.3	100	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Key : QU=quatz; FE=feldspar; PL=plagioclase; RE=rest group light min.; OP=opaque

PARTICLE SIZE DISTRIBUTION: weight %. WDIS CLAY: water-dispersible clay, weight %. BULK DENS: bulk density, g cm^{-3}. pF: moisture content, volume %. SSA: specific surface area, m^2 g^{-1} soil. ORGANIC MATTER: weight %. EXCHANGEABLE BASES, EXCH. H+Al, EXCH. Al, CEC, ECEC: $cmol_c$ kg^{-1}. ELEMENTAL COMPOSITION, EXTRACTABLE Fe, Al, Si, Mn, P-ret. (P-retention), SAND MINERALOGY: weight %.

APPENDIX 2

UNEP ISSS-AISS-IBG ISRIC

World Soils and Terrain Digital Database (SOTER)

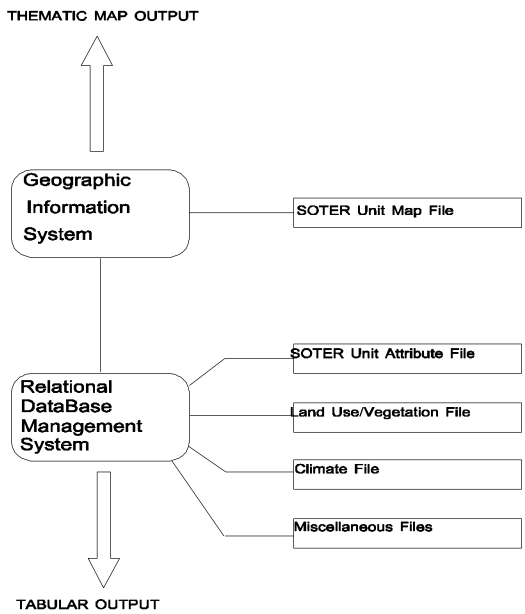
BACKGROUND

Policy-makers, resource managers and the scientific community at large have repeatedly expressed the need for ready access to soil and terrain resources through geo-referenced databases in order to make assessments of the productive capacity of soils, to have a better understanding about the risks and rates of soil degradation and to better quantify processes of global change.

The SOTER programme is a system which can store detailed information on natural resources in such a way that these data can be readily accessed, combined and analysed from the point of view of potential use, in relation to food requirements, environmental impact and conservation.

SOTER CHARACTERISTICS

SOTER provides an orderly arrangement of natural resource information through the creation of a computerized database containing all available attributes on topography, soils, climate, vegetation and land use, linked to a Geographic Information System, through which each type of information or combination of attributes can be displayed as a separate layer or overlay, or in tabular form.



SOTER DEVELOPMENT

SOTER is an initiative of the ISSS and was adopted at the 13th World Congress of Soil Science in 1986. Under a UNEP project, ISRIC developed a methodology for a World Soils and Terrain Digital Database (SOTER) for use at a scale of 1:1 M, in close cooperation with the Land Resources Research Centre of Canada, FAO, and ISSS.

SOTER was tested in three areas, involving five countries (Argentina, Brazil, Uruguay, the USA and Canada), using local data. Results were reported at the 14th World Congress of Soil Science in 1990. The ISSS Working Group on world soils and terrain digital database endorsed the methodology.

Based on the experience obtained in the pilot areas the SOTER methodology was further refined and a training programme and course materials were developed by ISRIC. In 1993 the Procedures Manual for Global and National Soils and Terrain Digital Databases was jointly published by UNEP, ISSS, FAO, and ISRIC (in English and Spanish), accompanied by attribute input software. A SOTER based methodology for an assessment of water erosion risk and for the Automated Land Evaluation System (ALES) was developed.

In 1993 the SOTER programme was implemented at national level in four countries (Argentina, Uruguay, Kenya, and Hungary). In Argentina and Uruguay, SOTER windows at scales up to 1:100 000 are also scheduled.

The national SOTER programmes are all formulated and financed by UNEP with technical support and coordination provided by ISRIC. The programmes are carried out by the national soil research organisations.

In 1992, the SOTER programme was evaluated by an international panel, convened by UNEP. The panel recommended not only SOTER activities at national level, but also the development of small-scale continental SOTER databases. In 1993, a joint action plan was formulated and jointly financed by UNEP, FAO, and ISRIC for the compilation of a Latin American SOTER at a scale of 1:5M. Some adaptations of the original methodology (designed for 1:1m scale) were necessary, such as the reduction of the number of attributes. In the first phase, six countries (Argentina, Brazil, Cuba, Mexico, Uruguay, and Venezuela) are involved and either have finished or are about to complete their contributions.

A Latin American SOTER workshop was held in April 1994 in Buenos Aires under the UNEP project as a starter for regular SOTER training workshop in the region. Representatives of many Latin American countries indicated their interest in participating in this continental SOTER programme. Compilation of its final phase depends on the availability of external funding. A workshop of the Data Information Systems on Soils task force of the International Geosphere-Biosphere Programme (IGBP-DIS), held in Washington D.C., in April 1994, recommended the use of a continental SOTER database for environmental global change modelling activities.

FUTURE

The number of requests for SOTER developments at a national level from countries in West and East Africa, South and Central America, Central and Eastern Europe, South and Southeast Asia is indicative of the demand for, and importance attached to the land resource database, land evaluation and land-use planning system which SOTER is capable of providing. Implementation will depend on available donor support.

ACKNOWLEDGEMENT

The catalytic and coordinating role of UNEP in bringing SOTER into reality is highly appreciated.

Name:	SOTER
Agent:	UNEP project, implemented by ISRIC, in cooperation with FAO and ISSS
Duration:	Long Term
Status:	In progress
Contact:	L.R. Oldeman or V.W.P. van Engelen

APPENDIX 3

UNEP

Global Assessment of the Status of Human-Induced Soil Degradation (GLASOD)

ISRIC

BACKGROUND

The United Nations Environment Programme (UNEP) expressed the need to produce, on the basis of incomplete knowledge, a scientifically credible global assessment of soil degradation in the shortest possible time. On behalf of UNEP, a World map of the status of human-induced soil degradation (GLASOD) at an average scale of 1:10 million was prepared by ISRIC (1988-1990) in close cooperation with over 250 soil scientists worldwide. The GLASOD map was presented at the XIVth International Congress of Soil Science in Kyoto, 1990, and at UNCED, Rio de Janeiro, 1992.

FOLLOW-UP

The map units of the GLASOD map were digitized and linked to a soil degradation database in which the attributes of soil degradation type, degree, frequency of occurrence, and causative factors of soil degradation are stored. It is now possible to estimate the global and continental extent of the various soil degradation types and their degree of impact. Single value maps of water erosion, wind erosion, chemical and physical degradation were prepared by UNEP/GRID and used in the production of the World Atlas of Desertification in 1992. Tabular data on the status of soil degradation were published in the World Resources Report 1992-1993 of the World Resources Institute. The results of GLASOD are also published by CAB International in the Proceedings of an International Symposium on "Soil Resilience and Sustainable Land Use", Budapest, 1992.

RESULTS

Human-induced soil degradation has affected almost 2000 million hectares (Mha) worldwide, or approximately 15% of the total land area. Water erosion is by far the most important type of soil degradation (56% of the total area affected by soil degradation). Wind erosion is of particular importance in the arid and semi-arid regions of Africa and Asia, while more than 50% of the land affected by nutrient depletion is in Latin America. Salinization is most dominant in Asia. Pollution as a result of industrial activities is of major concern in Europe.

Altogether more than 300 Mha of land is strongly degraded and has virtually lost its productive capacity. About 900 Mha is moderately degraded, characterized by a serious decline in productivity. However, this land can be restored if rehabilitation is implemented now.

Overgrazing, deforestation and mismanagement of the agricultural land, occurring on respectively 680 Mha, 580 Mha and 550 Mha are the major causes of human-induced soil degradation.

Global and Continental Extent of Human-induced Soil Degradation (in million hectares)							
Degradation type	Africa	Asia	Latin America	North America	Europe	Oceania	World
Water Erosion	227	440	169	60	114	83	1093
Wind Erosion	187	222	47	35	42	16	549
Nutrient Depletion	45	14	72	-	3	+	134
Salinization	15	53	4	+	4	1	77
Pollution	+	2	+	-	19	-	22
Acidification	2	4	-	+	+	-	7
Compaction	18	10	4	1	33	2	68
Waterlogging	+	+	9	-	1	-	11
Subsidence	-	2	-	-	2	-	4
Total	495	748	305	97	218	102	1965
Land Area affected	17%	18%	15%	5%	23%	12%	15%

FUTURE ACTIVITIES

Frequent requests have been made for more detailed regional and national estimates of soil degradation. The World Resources Institute indicated "a critical need for further study to more accurately portray soil degradation problems at a national and local level and to link soil degradation with its social and economic consequences". There are now proposals tabled for Mapping of Soil and Terrain Vulnerability in Central and Easter Europe (see "SOVEUR"), and for a Soil Degradation Assessment for countries in South and Southeast Asia, as recommended by the Expert Consultation of the Asian Network of Problem Soils (Bangkok, October 1993).

ACKNOWLEDGEMENT

The catalytic and coordinating role of UNEP in bringing SOTER into reality is highly appreciated.

Name:	GLASOD
Agent:	UNEP project, implemented by ISRIC, in cooperation ISSS
Duration:	5 years (1988-1990; 1991-1993)
Status:	Completed
Future:	New proposals formulated
Contact:	L.R. Oldeman

Land quality indicators: aspects of land use, land, soil and plant nutrients

The UN Commission on Sustainable Development (CSD) in its work programme indicated the need for indicators of sustainability linked to each issue discussed in Agenda 21. Among the well over 100 indicators defined, two refer to Agenda 21 Chapter 10, the Integrated Planning and Management of Land Resources. These are Land Use Change and Land Condition Change (change in the aggregate of the land qualities). Their descriptions, in the form of standard CSD methodology sheets, are provided at the end of this chapter.

It will be clear that the land condition indicator subsumes everything that is being discussed in the present Consultation on Land Quality Indicators. Here lies the core problem of the CSD effort. Unlike the relatively narrow economic indicators traditionally used by governments, central banks and the World Bank and regional development banks, which can summarize various aspects of the economy in a single, monetary variable, the land condition indicator is essentially multi-dimensional (as is the land use indicator).

The monitoring of broad changes in land use and in general land conditions will enable governments to report on the general improvement or deterioration of the state of the natural resources in their countries, using standard methods that allow comparisons between countries and between years. However, such broad, very highly aggregated indicators will not be useful in support of policy development, either national or at more detailed scale.

For practical purposes of policy advice or management advice, much more detailed, disaggregated indicators will be needed. In fact, the more detailed and specific the information requirements, the less the concept of land quality indicators makes sense, and the more evident is the need for actual observations on specific land use changes and on specific aspects of land condition, of physical, biological and chemical soil conditions, and of plant nutrient stocks and availability of plant nutrients in soils.

LAND USE

Is land use change an indicator of a driving force, state or response? Land use changes are generally conscious, volitional responses by humans or human societies to changes in biophysical or societal conditions. It is a response indicator, therefore, reflecting how and to what extent society is responding to meet its changing needs and goals or to adapt to changing environmental conditions. This does not exclude the possibility that some land use changes may, in turn, constitute a driving force for changes in the state of the environment. That is in the very nature of the complex causal network (not a simple causal chain), including a number of feedback loops, that is society's relationship with its environment.

R. Brinkman, Land and Water Development Division,
FAO, Rome, Italy

As suggested in the brief description in the standard format, it is virtually impossible to aggregate land use changes into a single, scalar indicator. The rates or extent of land use changes can be represented in the form of a transition matrix of land uses, showing the transition between each pair of uses as extent or proportion of area per unit time. An example of such a transition matrix can be found in the Forest Resources Assessment 1990 (FAO, 1995 pp. 35-36) for different kinds of forest and woodland versus broad categories of non-forest.

In the absence of a widely accepted, systematic set of land use definitions, it was not possible to compare land uses between countries or continents except in the most general terms. The concept of land use as a sequence of management activities in relation to a given area of land (Sims, 1986 and Terms of Reference for Land Use Description Systems, unpublished, 1990) has enabled FAO, jointly with several partners, to embark on a computer-aided system of land use description usable at several levels of detail, and on an effort to arrive at a system of land use classification that serves as a standard translator between different local or regional land use information sources.

It is now possible to map and report on land uses in a consistent manner across countries and regions. Part of the needed information can be obtained by translation or interpretation of existing local land use data as indicated above. A major part can be obtained by interpretation of remote sensing data with limited ground verification to produce land cover maps (land cover is the physical vegetation or crop cover resulting from natural processes or human activities). The land cover data then need to be complemented through more detailed field work with the more specific land use information (the management activities that characterize the system of use) to arrive at a land use map.

LAND

As is the case for land use change, it is doubtful whether a single, aggregate measure of land condition or land condition change would be feasible. What is feasible in principle is an estimation of the change in the different land qualities that influence the suitability of the land for one use or another, or for conservation - for example, of biodiversity. (Land qualities are discussed in FAO, 1976.)

The data needed for interpretation of changes in land qualities can be derived in part from remote sensing, complemented by ground survey observations. These should be combined with more frequent and thorough monitoring at selected permanent benchmark sites and long-term land productivity trial sites. Information is needed on aspects such as nature and density of vegetation or nature and productivity of crops (partly overlapping data with land use); conditions of the land surface (slope, runoff and erosion rates, sediment transport by wind, surface salinity); hydrological conditions (flooding incidence, groundwater dynamics); and physical, biological and chemical conditions (toxins, nutrients) of the soil. Such monitoring information, superimposed on a baseline soils and terrain database, will allow the estimation of potential productivity changes of land under different main uses and of suitability changes for different purposes such as conservation of native vegetation or animal populations. The institutional framework that would make such systematic, repetitive monitoring feasible does not yet exist in many countries.

SOIL

The soil, as a major subsystem of land, is changing with time consequent on changes in its environment (e.g., rainfall) or in management (grazing intensity, crops, irrigation, inputs, etc.). Land use or management decisions at any scale, from individual farm family to nation, need information about the soil system and its relationships with the environment and with management options. These relationships, as in the case of land use, are complex, with feedbacks providing different metastable situations and non-linear, sometimes delayed, responses to change. This implies that some changes in external conditions may not cause a perceptible change in the soil condition, while others may cause acute, or gradual, degradation or improvement.

Figure 1 shows the complex of processes that may lead to more biologically active and productive soils with a gradual rise in concentration of atmospheric carbon dioxide, as has started in the last century and is expected to continue for at least several decades. Clearly, a simple soil condition indicator cannot capture such processes. That will require both modelling and monitoring of a range of variables.

Even in a less complex system, in which monitoring shows increasing runoff and consequent gully formation in sloping soils, for example, such a change in soil condition cannot by itself be used to diagnose the proximate or underlying causes and does not contribute to identification of the most appropriate responses. These might be as diverse as advising the land users to change crop rotations or plant dense contour lines of permanent crops, or improving access roads or markets in the area, or enabling the users to obtain secure, long-term land tenure.

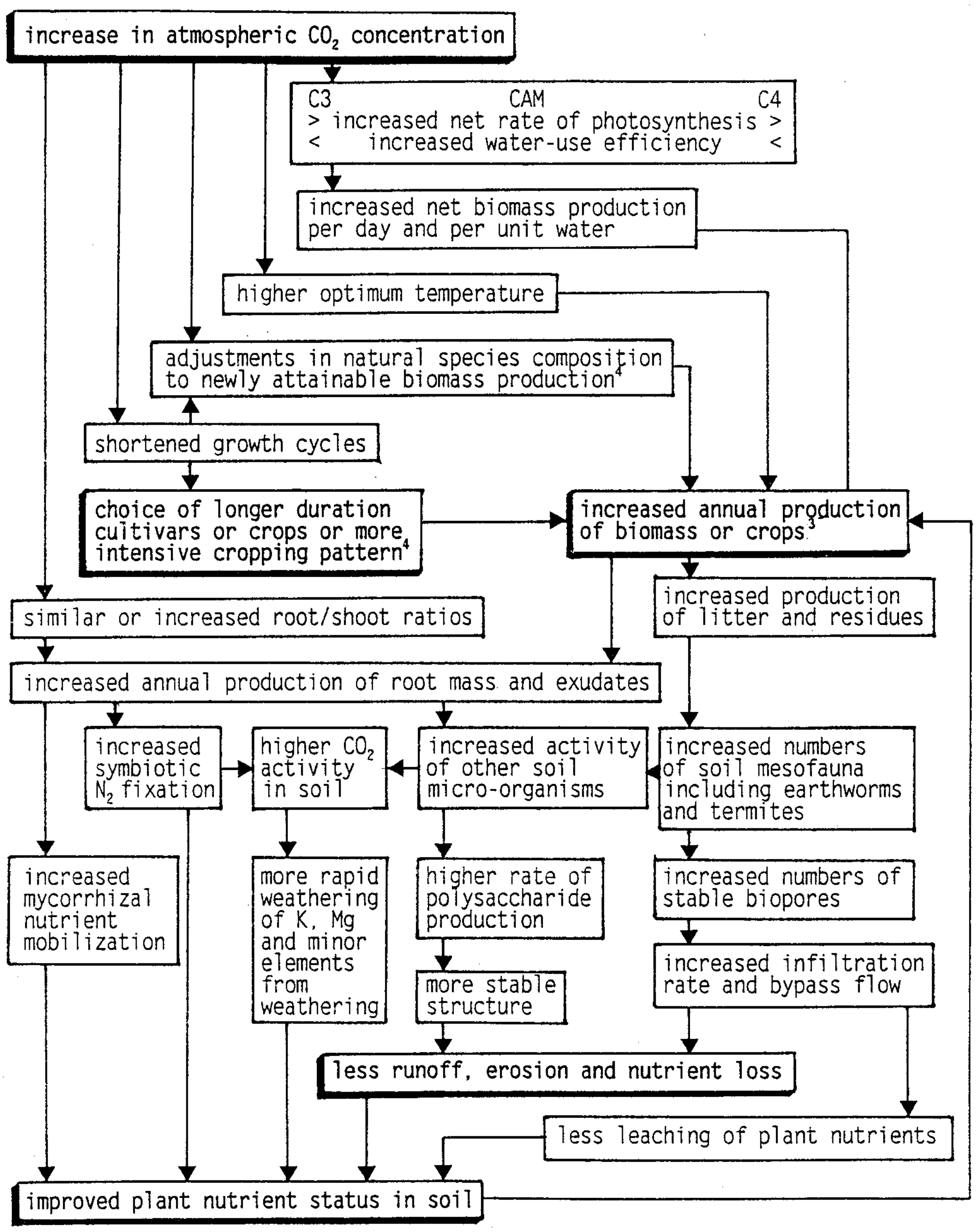
In every case, the system as a whole will need to be understood rather than one possibly diagnostic or indicative element, before sound responses can be identified and put into practice.

PLANT NUTRIENTS

Descending another step, into the plant nutrients or soil fertility subsystem of soil, one finds similar complexity. Nitrogen deficiency, for example, may be caused by a low content of decomposable organic matter in the soil, or by a high groundwater table, and remedied by applications of manure or appropriate fertilizer or green manuring, or by land drainage. Similarly, zinc deficiency in wetland rice may be caused by an absolute zinc deficiency, or by poor availability of zinc due to fixation in the presence of calcium carbonate, or by very gradual, but strong fixation where soils remain continuously wet and reduced for long periods, without drying between rice crops. So even at this level of detail, single indicators may be meaningless until the related factors in the system are known and the system as a whole is clearly understood.

FIGURE 1

Qualitative relationships between gradually increasing atmospheric CO₂ concentration[1], soil characteristics and medium-term processes in soils[2], and biomass or crop productivity[3]



[1] Gradually rising CO_2 as in this century and in transient global change scenarios.
[2] Soils with some weatherable minerals at least in the subsoil or substratum within rooting depth.
[3] Extreme weather events may disrupt some relationships in the figure, so any major increase in their frequency or intensity may counteract positive effects shown.
[4] Species composition adjusts, or choices indicated are made to adjust, to the newly attainable biomass or crop production under increased atmospheric CO_2, compensating for shortened growth cycles of existing species or crops. The figure does not include the positive effects of higher temperatures on length of growing periods in temperate or boreal climates.

CONCLUSION

In brief, land quality indicators may in future have a useful function on a world scale and for national reporting, for example to UN CSD. But for any more detailed or specific purposes, such as policy advice at national level, or management or planning advice in provinces or districts or smaller farming areas, indicators would not provide the sound, process-based information needed. That can only be derived from investigations using real data, interpreted for the purpose rather that aggregated *a priori* using a predetermined procedure.

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FAO. 1976. A framework for land evaluation. *Soils Bulletin* **32**. FAO, Rome.

FAO. 1995. Forest resources assessment 1990; global synthesis. *Forestry Paper* **124**. FAO, Rome.

Sims, D. 1986. META: A New Approach, *AGL Land and Water Newsletter* No. **26**, August, 1986.

APPENDIX 1
UNDPCSD/FAO METHODOLOGY SHEETS
UNCED AGENDA 21, CHAPTER 10: PLANNING AND MANAGEMENT OF LAND RESOURCES

LAND USE CHANGE

1. **INDICATOR**

(a) *name of the indicator:* Land use change.

(b) *brief definition of the indicator:* Change with time of distribution of land uses within country.

(c) *unit in which the indicator is measured:* Proportion of change of given land use per unit time.

2. **PLACEMENT IN THE FRAMEWORK**

(a) *chapter of Agenda 21:* Chapter 10, Planning and management of land resources.

(b) *type of indicator (Driving Force, State or Response):* Response (mainly).

3. **SIGNIFICANCE**

(a) *purpose of the indicator (the phenomenon it is meant to represent):* Highlight changes in productive or protective uses of the land resources.

(b) *policy relevance:* Consequent changes in volume of produce available; and in scope for providing services such as tourism or environment.

(c) *relevance of the phenomenon to sustainable/unsustainable development (interpretation, value, movement):* Evident from 3(b).

(d) *close linkages between this indicator and other indicators in the list (e.g. is this indicator better interpreted if paired or combined with (an)other indicator(s)?:* With land **condition** change (Chapters 10 and 14).

(e) *targets (do international targets exist? does the indicator lend itself to the establishment of national targets? how does this indicator relate to existing targets?):* No. Except for establishing certain minimal contiguous extent, or proportions of total, for certain needed or desirable land uses.

(f) *reference to international conventions or agreements:*

4. **METHODOLOGICAL DESCRIPTION OF THE INDICATOR AND THE UNDERLYING DEFINITIONS**

(a) *underlying definitions and concepts (description of the elements of the indicator, concept availability (are the concepts readily available? does the indicator need further work? are the concepts lacking? from where are the concepts available?):* AGL and partners in and outside FAO developing:

- computerized land use database structure;
- broadly accepted structure of land use classifications.

(b) *measurement methods (how is the indicator measured and computed?:* By periodic mapping and monitoring land uses, **partly** on the basis of land cover information from remote sensing, partly by ground check; also, relation with land use aspects of agricultural census.

(c) *description of the indicator in relation to the DSR framework:* A response indicator. The response is the resultant of several driving forces, both past and current. These include demands for produce and services from within the country and from abroad, as modulated by price relationships, terms of trade and non-financial barriers to trade, domestic and international; by rural population growth as modified by immigration; by national and customary law and policy environment; by infrastructure and services available; and by the biophysical potentials and qualities of the land (soils, landforms, agroclimate, water availability...).

(d) *limitations of this indicator:* Does not by itself help identify nature of causes (driving forces).

(e) *alternative definitions of the indicator and possible consequences of variations in the definition:* -----

5. **ASSESSMENT OF AVAILABILITY OF DATA FROM NATIONAL AND INTERNATIONAL SOURCES**

(a) *which data are needed to compile the indicator:* Dependable agricultural census data on land uses and dependable land use maps, (updated at intervals).

(b) *are the data available? (most countries? some countries? a few countries? on both a national and sub-national level? on a regular basis?):* For only few countries to date.

(c) *data sources:* National governments.

6. **AGENCIES INVOLVED IN THE DEVELOPMENT OF THE INDICATOR**

(a) *lead agency, including contact point:* FAO; AGL (D. Sims), UNEP.

(b) *other organizations, Governments or major groups which have been involved:* None.

7. **FURTHER INFORMATION**

(a) *further readings:* Documents under development.

(b) *other references for additional information (including document citation):* Documents under development.

(c) *and contact points:* ITC Enschede Netherlands (International Institute for Aerospace Survey and Earth Sciences); ITE, UK. (Institute for Terrestrial Ecology).

(d) *indication as to whether or not methodology has already been agreed upon by an intergovernmental fora and if it has the status of (1) recommendations, (2) guidelines, or (3) a technical report:* No.

LAND CONDITION CHANGE

1. **INDICATOR**

(a) *name of the indicator:* Land condition change (Change in land qualities).

(b) *brief definition of the indicator:* Changes, disaggregated by type and geographic location, in the nature of the land resource. These may be of very different type, including:

- physical soil condition;
- diversity or density of vegetation cover;
- thickness of topsoil (by erosion or, conversely, by good management);
- salinity or sodicity (alkaline conditions);
- terracing;
- establishment of contour vegetation strips.

(c) *unit in which the indicator is measured:* areal extent and magnitude of change of the types under 1 (b), with improvement and deterioration reported separately.

2. PLACEMENT IN THE FRAMEWORK

(a) *chapter of Agenda 21:* Chapter 10, Planning and management of land resources (this indicator subsumes the originally-proposed "area of land reclaimed").

(b) *type of indicator (Driving Force, State or Response):* State.

3. SIGNIFICANCE

(a) *purpose of the indicator (the phenomenon it is meant to represent):* Changes in the productive capacity, the environmental quality and the sustainability of the national land resource

(b) *policy relevance:* Clear information available on (i) potentially harmful trends to be addressed and "turned around," and (ii) favourable developments in qualities of the land resource, either due to past policy intervention or as by-products of other human actions or natural developments.

(c) *relevance of the phenomenon to sustainable/unsustainable development (interpretation, value, movement):* See 3(b) above.

(d) *close linkages between this indicator and other indicators in the list (e.g. is this indicator better interpreted if paired or combined with (an)other indicator(s)?:* It relates to land use change and indicators in Chapters 11, 12, 13, 14, 15.

(e) *targets (do international targets exist? does the indicator lend itself to the establishment of national targets? how does this indicator relate to existing targets?):* No international targets exist or apply. National sub-targets for individual types of change can be useful, for example in the reclamation of salt-affected land or the restoration of land damaged by erosion.

(f) *reference to international conventions or agreements:* No formal conventions or agreements, but three less formal documents:

- World Soil Charter, adopted by FAO Conference 1981;
- The International Scheme for the Conservation and Rehabilitation of African Lands (ARC/90/4), adopted by the Africa Regional Conference 1990;
- The den Bosch Declaration and Agenda for Action on Sustainable Agriculture and Rural Development, FAO and Government of the Netherlands, 1991.

4. METHODOLOGICAL DESCRIPTION OF THE INDICATOR AND THE UNDERLYING DEFINITIONS

(a) *underlying definitions and concepts (description of the elements of the indicator, concept availability (are the concepts readily available? does the indicator need further work? are the concepts lacking? from where are the concepts available?):* Concepts and definitions of land and soil degradation are available, e.g., in the GLASOD Study. The current work by Berne University/Swiss Development Cooperation, World Association for Soil and Water Conservation, FAO on WOCAT (World Catalogue of Conservation Approaches and

Technologies) will provide concepts and information on extent of different types of land conservation practices.

(b) *measurement methods (how is the indicator measured and computed?:* By extent of land improved or deteriorated, specified by type of change. Suggested monitoring intervals of the order of 5-10 years.

(c) *description of the indicator in relation to the DSR framework:* State indicator. Deterioration due to pressures on land with consequent mismanagement or insufficient inputs, etc.; improvement by conscious policy intervention with consequent better management, because of natural restorative processes or by-products of sustained good land husbandry.

(d) *limitations of this indicator:* Difficulty in collection of sufficient data detail. Simple comparison between countries is not possible.

(e) *alternative definitions of the indicator and possible consequences of variations in the definition:* N.A.

5. ASSESSMENT OF AVAILABILITY OF DATA FROM NATIONAL AND INTERNATIONAL SOURCES

(a) *which data are needed to compile the indicator:* Soil survey, land cover, soil degradation assessment, estimates of extent of different land improvements since previous census.

(b) *are the data available? (most countries? some countries? a few countries? on both a national and sub-national level? on a regular basis?):* Not in systematic form, except in very few countries. Some available at world level (1:5 million and 1:10 million scales), or at national level.

(c) *data sources:* Soil survey institutes; agricultural census if specific reasons for abandonment are listed; remote-sensing data collections.

6. AGENCIES INVOLVED IN THE DEVELOPMENT OF THE INDICATOR

(a) *lead agency, including contact point:* FAO; AGLS, R. Brinkman, R.Gallacher, F.O. Nachtergaele.

(b) *other organizations, Governments or major groups which have been involved:* -----

7. FURTHER INFORMATION

(a) *further readings:* Guidelines for Agro-ecological zone studies (in press); Soils bulletin 67 and World soil resources report 71 and 71/1-9; GLASOD Study; World soil resources report 74: Global and national soils and terrain digital databases (manual) FAO, Rome.

(b) *other references for additional information (including document citation):* -----

(c) *and contact points:* -----

(d) *indication as to whether or not methodology has already been agreed upon by an intergovernmental fora and if it has the status of (1) recommendations, (2) guidelines, or (3) a technical report:* No.

Farming systems indicators for sustainable natural resource management

The paper presents some preliminary conclusions derived from a case study carried out in the West Usambara Mountains, Tanzania, for the Farm Management and Production Economics Service of FAO. The case study attempted to identify indicators for sustainable farming systems using a combination of quantitative and qualitative data. One key innovation of the sustainability discussion into the development paradigm is the increased emphasis on the time dimension in natural resource management. As natural resource parameters generally change slowly, particularly the soil-related ones, the time horizon for measuring of relevant parameters can easily reach a decade. A cheap and quick approach using proxy-indicators and relating them to existing historic data should reduce this time span.

The case study assessed the changes in the farming system through the use of historic, small questionnaire surveys in five villages in the West Usambara Mountains. These data were complemented with qualitative data on the reasons for change as well as strategies for nutrient management as one component of the farming system. As agricultural production is only one of many farmer activities, the agricultural system was put into the broad context of off-farm and non-agricultural components of the farming systems. Interview partners for the qualitative data collection were farmers, key informants such as village authorities, head teachers, project and church personnel. The paper presents selected examples of proxy indicators at the field, cropping system and farming systems level. Special emphasis is given to the possibilities of using the nutrient balance in cropping systems as an alternative to the measurement of soil fertility parameters.

There is a need to identify indicators at a higher level than the field level, but below the level of agro-ecological zones. The reasons are that farmers as the managers of the natural resources are the ultimate decision-makers about the implementation of any conclusions derived from indicators for unsustainable resource management. These indicators consequently have to consider the farmers' decision-making processes concerning their resource management. Indicators need to cover the natural resource domain, but simultaneously have to consider the socio-economic sphere shaping farmers' behaviour.

BACKGROUND

Concern about the possibilities for future generations to meet their basic needs was the main reason for the change in development paradigm in the late 1980s, the origins of which can be traced back to earlier studies such as Global 2000 or even the work of Robert Malthus in the 19th century.

H. Wattenbach and K.H. Friedrich, Agricultural Support Systems Division, FA, Rome, Italy

These publications highlighted the problems for feeding the world's population and maintaining the livelihood system under existing population growth rates and with limited natural resources. The underlying assumption of these studies of linear trends has been frequently criticized, but the concerns about the potential negative impacts of present growth on future generations have been revived by more differentiated analyses. These concerns have received worldwide attention and focus under the term "sustainable development".

> "Sustainable development is development that meets the need of the present without compromising the ability of the future generations to meet their own needs. It contains within it two key concepts:
>
> ; the concept of "needs", in particular the needs of the world's poor, to which overriding priority should be given; and
> ; the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." (WCED 1987, p. 43).

The major conclusions at international level have been discussed and agreed upon at the Earth Summit held in Rio de Janeiro in 1992 with the adoption of the United Nations Programme of Action from Rio. However, despite the changes in the global and general development perspective from short-term improvements to a long-term perspective, the operationalization of the term "sustainability" is still lacking.

CONTEXT OF THE STUDY

Most natural resources of the world are presently still being used by farmers. Therefore, the successful implementation of any conclusions derived from the monitoring of indicators for sustainable resource management will depend on their acceptance by the farmers. It is believed that an understanding of the farmers' resource management system is indispensable to be able to implement sustainable resource management concepts. The indicators for sustainability needed to monitor and evaluate modified development concepts will consequently have to consider the farmers' decision-making process about the use of the natural resources at their disposition. Several names for approaches which aim at understanding these mechanisms are being used, the most prominent one of them being the farming system concept.

A farming system is a natural resource management unit operated by a farm household, and includes the entire range of economic activities of the family members (on-farm, off-farm agricultural as well as off-farm non-agricultural activities) to ensure their physical survival as well as their social and economic well-being. This broad definition is of importance, as the farm family takes decisions considering not only the farming possibilities, but also the off-farm employment opportunities. Within an agro-ecological zone, several farming systems will typically be found, with variations in resource endowment, preferences and socio-economic position of the respective family.

Based on these considerations, the case study tested an approach to determine indicators relating to the sustainability of farming systems. The approach should meet two additional criteria:

; yield a result after a relatively short period of time, i.e., the study should not be a long-term research project;
; be repeatable by independent local research teams, i.e., be based on moderate or nil external inputs.

This excluded from considerations the measurement of any indicators requiring repeated data collection over several years. Instead, the approach had to consider finding proxy indicators substituting these data collections by other appropriate means.

The important question: *"What should be sustained?"* was preliminarily answered as follows:

> *"In order to achieve sustainable use of natural resources, farmers must be able to ensure a non-negative trend in real (per caput) income."*

This statement by itself does not yet provide an operationalized approach to derive indicators. In order to achieve this, decisions had to be made to define the appropriate level of assessment within the systems hierarchy, to determine the time dimension to be considered and to specify data sources.

CASE STUDY

The case study is based on two field visits of one month each by two international researchers[1] to the West Usambara Mountains and data collection by three local researchers for two to three weeks. The aim of the first visit of the international researchers was to identify the field study villages, to become familiar with the study area, to adapt and test the questionnaires, and to identify and review major sources of secondary data. The second visit was carried out after completion of the questionnaire survey and encompassed the review of secondary information as well as data collection using qualitative methods. The following includes a brief description of the approach and a discussion of those conclusions relevant in the context of land quality indicators. A more detailed presentation of the results of the study will be made in a forthcoming publication in the Farming Systems Management series of FAO.

Dealing with the "TIME DIMENSION"

The time dimension of development requires strong emphasis on dynamic variables. To meet the complementary criterion of avoiding long-term research studies, there were two options for dealing with the dynamics of the systems: a) through proxy indicators and b) comparison of data over time.

The latter was possible, as there exist historic farming system studies in the West Usambara Mountains. Two sets of data were available, one from a study carried out in three villages in 1965 (Attems, 1967; 1968) and the second study carried out in 1985 (Due *et al.*, 1985) in two other villages. The original questionnaire forms for both studies were available. These were used in a modified version (not all questions were found suitable to be repeated) and a sample of farmers was interviewed by local consultants in four of these five villages.

[1] W. Grisley and H. Wattenbach undertook the first mission and M. Hall and H. Wattenbach participated in the second mission.

The questionnaire covered all aspects of farming systems, such as family composition, land and livestock ownership, cropping pattern, forest resources on the farm as well as sources of non-agricultural income, among others. The comparison of these sets of data was expected to describe changes in the farming systems over two periods of time.

The mere description of changes without information on the driving forces behind them would leave an incomplete picture and yield unsatisfactory indicators, if any. Therefore, the questionnaire data were complemented by secondary sources on changes in macro-economic parameters such as price, major policy shifts, net population numbers for the area, infrastructural development, reports about the ecological situation (forest, soil and water resources, as available) of the district, etc.

During the second field visit by the international researchers, elements of rapid rural appraisal were used to collect information on, among others, the farmers nutrient management strategies, and the farmers' interpretation of changes in their livelihood system within the last decade. These questions were directed to farmers' groups (men and women groups), key informants such as school head teachers as well as project, church and NGO staff. The specific intention behind these discussions was to assess the reasons for change in resource use and to receive information about the farmers' perspective of the future development of their livelihood system. The methods used to achieve this were the drawing of resource flow charts, discussions with farmers during transect walks, and inviting farmers' reactions to a presentation of the changes identified in the questionnaire interviews in combination with open questions on the subject.

Dealing with the "SYSTEMS HIERARCHY"

Potential aggregation levels for indicator testing include the individual soil erosion or soil structure measurement points, the field, the cropping system, the farming system, the watershed, an agro-ecological zone, administrative units or the agricultural sector of a country. As the case study aimed at defining indicators for agriculture-based systems, the biophysical resource base was the starting point of analysis. Farmers frequently make specific decisions on how to use certain parts of a given field, based on their long-term observation of soil type, insect infestation and other biophysical factors. However, for the purpose of this study, the minimum level for assessment was the field. The cropping system and the crop rotation at field level were assessed through formal questionnaires.

The results of indicator assessment at any of the above-mentioned levels may be aggregated to the next higher level, if information on the geographical distribution of the respective unit is known and the relative weights of the different values for that indicator have been established. For example, soil erosion status at plot level may be estimated on the basis of soil erosion measurement points, as long as their distribution satisfactorily describes the soil erosion status of the field. In addition, the weights given to the indicator levels of different measurement points need to be established. In other words: is there an absolute limit for an indicator, beyond which that unit could not be sustainable (according to that indicator)? Or, should the definition of a higher level indicator permit that the values of two measurement points compensate each other?

Erosion on one part of a slope, for example, is certainly a negative indicator for the long-term ecological sustainability of that soil unit. But, assessing the situation from a larger perspective could show that the soil is accumulated at a different part of the slope and being used by the farmer for producing valuable crops, for which the growth conditions might not have been suitable, without more fertile material accumulated through erosion. It may therefore happen that the soil erosion on that aggregate unit is negligible and considering the farm-household system, the shift of soil may stabilize the farmers' income possibilities. In other words, external factors at a lower level (erosion on site A) may become internal at a higher level (e.g. a broader geographical unit including points of soil erosion and soil accumulation).

For practical purposes, it was decided that the case study would:

; start at the field level and attempt to identify the nutrient balance at the cropping systems level through proxy indicators (assessed through discussions with individual farmers and small groups, complemented by information from the questionnaires);

; identify the importance of the cropping system in the case study villages and assess the changes in relative importance of the cropping systems in the study period (assessed through the questionnaire survey as well as one group discussion);

; determine changes in the farming system (relative importance of different crops, off-farm employment and plans for the future) through a combination of questions answered during the questionnaire interviews as well as rapid assessment methods.

The questions focusing on the farming systems referred to the relative importance of different sources of income, shifts in their relative importance and the reasons why these changes occurred. Major changes included the reduction in coffee cultivation and wattle trees over time, the expansion of vegetables (partly in combination with increased terracing) and beans in certain areas of the mountains.

Major changes at the village level were reported on the use of off-farm natural resources such as forests and communal grazing areas. These types of changes were most clearly identified through interviews with key informants in villages and with NGO representatives. The reasons given for these changes were changes in village and district level by-laws such as the abolition of free grazing systems, and changing attitudes towards forest use on hill-tops. Changes in the latter were particularly emphasized under the extension advice provided under different phases of the Soil Erosion Control and Agroforest Project (SECAP).

This information on the plant production subsystem was complemented by the information collected about the livestock and forestry subsystems. Livestock is important as a provider of manure and user of grasses and by-products as feed. In semi-arid and arid areas, livestock is frequently accused and sometimes positively identified as a major cause of resource degradation. During the case study, the sources of livestock feed, the grazing regime as well as the manure use strategies were assessed qualitatively. Given the relatively low livestock numbers, the extensive feeding regime and low intensity, its contribution to the plant nutrient balance (and also soil structure) is almost negligible on most farms. Nevertheless, it could reach considerable importance for an improved nutrient management system, given that the demand for livestock and particularly dairy products could increase substantially in the regional economy.

Even though it is undisputed that most tree species have a positive effect on the long-term sustainability of ecosystems, their specific contribution is difficult to put into context when a relatively large number of tree species occurs scattered in the farmers' fields. Deriving indicators on the sustainability of cropping systems from information on the numbers of different tree species will require further consultation with experts in that field.

The changes in the farming systems have taken and are taking place in the context of a great number of changes in the institutional and political setting of Tanzania. These include changes in the price structure, the marketing system for inputs and produce and the infrastructure of the area. These changes already led to a rapid expansion of the area under beans and vegetables and may lead to a major increase in coffee production in the future, reversing the decline of the industry in the last decades. Simultaneously the decline in prices for the bark of wattle trees and the recent closing of the wattle extraction plant may stimulate further land-use changes in parts of the mountains.

Examples of indicators based on rapid assessment methods

Examples of the reasoning followed in the case study for testing simple indicators at different aggregation levels are presented below:

; Field level indicators

The assessment of sustainability at the plot level mainly addressed the physical and ecological aspects of sustainability. The determination of the nutrient balance and its trend over time through proxy indicators was tested as an alternative to a long-term measurement of physical data.

Sustainability at the field level should reflect the capacity of the agricultural production system on that specific field to maintain a certain yield in the future. In a first step, sustainability at the field level shall be defined as the possibilities for continued cultivation of the same cropping sequence. There are two possible approaches to assess the production potential:

- to derive the trend in the production capacity from the physical properties of that field. This would require the assessment of these properties, their monitoring over a sufficient period of time and the estimation of the changes in production potential for certain crops over time. The most prominent physical parameters would be related to the soil (organic matter content, physical soil structure (pore structure), soil type, water retention capacity, nutrient content, erodibility of the topsoil, etc.). These data would be complemented with climatic data so that the crop or fodder production potential could be derived from the most important agro-ecological parameters. It should be noted that sustainability indicators would have to reflect the status of the variable over time. Two reasons led to the conclusion not to attempt this approach: even in a relatively favourable situation of data availability in the West Usambara Mountains, there are hardly any relevant soil data for the past, and even for the few soil research sites of the past the exact location of these sites would have been quite difficult. In addition, the combination of any such data with sufficiently detailed climatic data in an area with such difficult topographic and consequently site-specific climatic data is close to impossible.

  Therefore, even the measurement of the required parameters in a short-term study would have been meaningless because of the lack of a reference system in the past. The only possible solution would be the direct measurement of relevant parameters and therefore a research project over a time span sufficiently long to allow the identification of changes of the parameters, probably exceeding a decade.

- to identify proxy indicators for the nutrient balance for the major crops cultivated in the research area; since the nutrient balance in a field will result in the more immediate effect on production potential than soil structural change, it should be given first priority during the assessment. The nutrient flows were divided into inflow and outflow: harvest, by-product removal, erosion, N-evaporation and nutrient leaching being the most important outflows and inflows comprising manure, fertilizer, mulch, by-products left or added to the field, mineralization, N-fixation and atmospheric addition of nutrients.

  Several of these parameters would be almost as tedious to assess as the above criticized soil parameters. However, it was expected that assessing only the most prominent of these parameters would be sufficient to allow statements about the trend on that plot and would therefore qualify as a proxy indicators. Through interviews information was collected on assessment of the yield level, the use of by-products from different crops, and applications of manure, fertilizer and mulch. This information was combined with information of the position on the slope to allow for adjustments for additional nutrient loss through erosion (or the addition of eroded nutrients in the valley bottom).

Two examples illustrate the argument: a field under 15-year old tree shrubs, which receive a relatively high level of annual fertilization is unlikely to be under a negative nutrient trend, even without measuring the nutrient loss through leaching and the nutrient input through mineralization. In contrast, a maize field on a relatively steep slope without leguminous crops, which is only cultivated one season per year and left fallow for the rest of the year, and which systematically does not receive manure or fertilizer, can be classified as an unsustainable production system. Attempting to measure the degree of erosion may help quantifying the total nutrient loss per year, but the negative trend is indisputable. The additional research budget which would be needed to measure nutrient inflows such as through mineralization in the soil is probably better invested in understanding the reasons why farmers accept the obviously negative nutrient balance.

Further dialogue is needed to determine under which situations such proxy indicators for the nutrient balance yield a satisfactory result and under which conditions more refined methods need to be applied.

; Cropping systems level indicators

Field level information was mainly assessed through the questionnaires, and their analysis resulted in information on the cropping system. As this type of information is generally also presented in historic farming system studies, changes in the cropping pattern can be assessed relatively easily through comparisons of older and new field studies. The questionnaires covered the following aspects: the cropping pattern per field from 1990 to 1995, distance of the field to the house, position of the field on the slope, steepness of the field and information about the farmers' assessment of change in productivity on that particular field compared to ten years ago.

The questionnaire information was complemented by discussions with the farmers about their strategies for nutrient transfer between fields. It was found that nutrient transfers occur in addition to crop specific strategies: the removal or addition of by-products depends in addition on considerations such as feed requirements for livestock, strategies for livestock grazing in the field after harvest, fertilizer application and application of manure to specific target crops and depending on the distance of the field from the house. It was again assumed that an identified negative nutrient balance in a cropping system based on the above assessment would not be reversed if other factors such as leaching and nitrogen fixation were to be assessed as well and that therefore the additional budget implications and time needed to do so should better be invested in researching other determinants of the farmers' resource management strategies.

; Farming system level indicators

The development of the farming systems takes place in the context of the village and watershed and of macro-economic trends. Farmers will adjust their cropping pattern and farming systems to these conditions, including off-farm employment opportunities, migration and concerns about the livelihood of their children. Any advice given to farmers on sustainable natural resource management will be put by them into the wider context of considerations about the development of their livelihood system.

Farmers therefore tend to give less weight to field-level, biophysical and ecological considerations than to sustainability of the whole farming system, which could include the acceptance of a transfer of nutrients between different fields, within the catena and from distant fields towards the homestead. And depending on the trends in the non-agricultural sector of a village, the farmers may even decide to shift emphasis from agricultural to non-agricultural activities (or vice versa). These shifts in importance were assessed in the formal questionnaires by asking ranking questions on the importance of different sources of income, which had also been determined - albeit by different means - in the previous studies. However, the estimation of the socio-economic sustainability of the farming system through qualitative means was more interesting in the present study.

Before addressing the farmers' perspective of their farming systems in the future, attempts were made to discuss with them their evaluation about the past development. In order to allow active contribution of the younger farmers, the time horizon for doing so was reduced to changes within the last decade. Such overall assessments will always depend on the socio-economic position of the interviewed person, and a long list of other factors. However, it was found useful to see which of the indicators used by the farmers would indicate changes in their overall well-being. Indicators listed by farmers themselves included corrugated iron sheets, increased installation of water pipes, increased availability of consumer goods in the villages and more meat available in the market.

Despite differences in the indicators chosen by men and women and by different individuals, a discussion is necessary on which of them directly indicates changes in the socio-economic well-being. Most items listed referred to consumption indicators. Among those, many reflect at the same time increased cash availability in the villages, but also changes in macro-economic import and marketing policies. These increased imports into the regions, but do not necessarily reflect the consumption potential before these changes occurred. It appears more relevant to review changes in the consumption of goods which where available already under the previous macro-economic system. Therefore, the availability of meat in the market appears to be a more promising indicator than corrugated iron sheets.

The need to assess the existing plans for changes in the farming system could potentially contribute further to the development of indicators for sustainability of the systems. Particularly during individual interviews, the importance of considering the social position of the farmer concerned became immediately obvious. The difference shall be illustrated through two examples:

> Example 1: a poor widow owns only one plot of land, which covers her basic needs for cassava and banana with small quantities of coffee for sale. She does not see any future for her children in the area, as land is increasingly difficult to borrow. Three of her four children already migrated out of the West Usambara Mountains, and the widow assumes that they will never return due to the lack of a resource base to fall back upon. Despite the relatively diversified cropping pattern on that single piece of land, there is no prospect for investment in soil erosion control on the steep slope where the field is located.
>
> Example 2: the son of a relatively large farmer returned from migration in the Lake Zone. He starts cultivation of a fairly large area with new technologies (vegetable cultivation on irrigated land, cultivation of sorghum for chicken feed and poultry production). His cropping system will be relatively more prone to erosion, but as the crops cultivated will be more profitable than those of the widow, he will have the resources to invest in soil erosion control should he wish to do so. In addition, the farmer is open to further modifications of his production technologies in case they meet his farming strategies.

These two examples illustrate a further dimension to the definition of indicators for the sustainability of farming system, which should guide assistance and interventions to help modify unsustainable systems. The resource availability in the family or the situation within the family life cycle has a strong influence on the farmers' strategies. Indicators on the farming system level may ultimately depend on the social and economic dynamic of an area. And more recently, new dimensions were added to the already complex determinants of the farming systems dynamics in the West Usambara Mountains. For example, the farmer returning from the Lake Zone stated that all of his plans for farming will depend on the development of his health situation, as his wife unexpectedly died in the Lake Zone and his own health situation has become quite unstable.

CONCLUSIONS

The case study yields conclusions on various issues. Some of them are related to difficulties arising from data collection through recruited staff, be it through questionnaire surveys or rapid or participatory appraisal techniques. Others are more specific to participatory methods, such as the creation of expectations by the farmers by the intensive work with them, which are not easily fulfilled in the context of case studies. The cooperation with an existing project made the execution of the case study relatively easy, but highlighted an important area for consideration for similar studies. Some more specific conclusions from the material presented above are the following:

; The usage of the terms "parameters" and "indicators" in the present discussion should be clarified. "Indicator" is the more widely used term and this was also the starting point for the case study. The intensive use of the logical framework method in the project cycle has led to extensive studies on the requirements which need to be fulfilled by indicators in order to qualify as a helpful tool for monitoring purposes. According to these, indicators have to be specified in terms of quantity, quality and time horizon.

The further complication of using indicators for sustainability is the inherent time dimension of the issue, in which a constant change in variables is expected. An intensive dialogue among the professional disciplines will be needed if practical conclusions are to be drawn from the indicators developed in the different disciplines. As the lead in this discussion will depend on the context of usage of the indicators, the weights given to certain types of indicators will vary. It can be expected, however, that the longer the lists of indicators, the more of them will be given relatively little attention in the aggregation process. An early and open dialogue across the technical disciplines in the matter would therefore increase the efficiency of research in the development of indicators.

; The bio-physical resource base has been the starting point of the discussion on sustainability and therefore holds a prominent position in attempts to identify indicators for sustainability. The minimum and maximum aggregation levels of data needed and/or permitted, however, need to be discussed in the context of the types of conclusions which should be drawn from these indicators.

; If the indicators should only be used for regional priority setting of agricultural and environmental policies, relatively high geographical aggregation levels and a relatively strong bias towards biophysical indicators might be acceptable. These indicators will then point out the regions or agro-ecological zones with the most urgent "average intervention need". However, this does not necessarily point to the most cost-efficient geographical or sectoral interventions, as these indicators may not allow drawing conclusions on the underlying problems leading to the need for intervention. The cost-efficiency of interventions will also depend on the monetary, social and administrative costs to implement programmes after identifying areas for intervention. These costs will depend on the magnitude and type of changes the farmers would have to make in their resource management system and is therefore a function of the farming system operated by the farmer.

; Similarly, should the indicators yield a detailed understanding of the soil physical and soil chemical mechanisms leading to ecologically unsustainable resource management practices, the development of indicators even below the field level may be necessary. In order to draw conclusions on the necessity for and acceptance of modified resource management systems, the farmers' decision-making process has to be taken into consideration. As the farmers differentiate their resource management not only on the basis of ecological variables (which will generally be included in data aiming at field level indicators of sustainability) but also on the basis of socio-economic factors such as accessibility of the field from the house, ownership security for different fields, etc. (which are usually not included in field level databases), the ecological variables by themselves are not sufficient for the development of intervention- and extension-oriented indicators.

; The discussion about the best stratification criteria of farming systems for the purpose of developing indicators for sustainable resource management is still at an initial stage. However, it is obvious that improved resource management can only be achieved if advice given to the farmers is based on an understanding of these systems. In times of increasingly restricted research budgets, proxy indicators should be developed.

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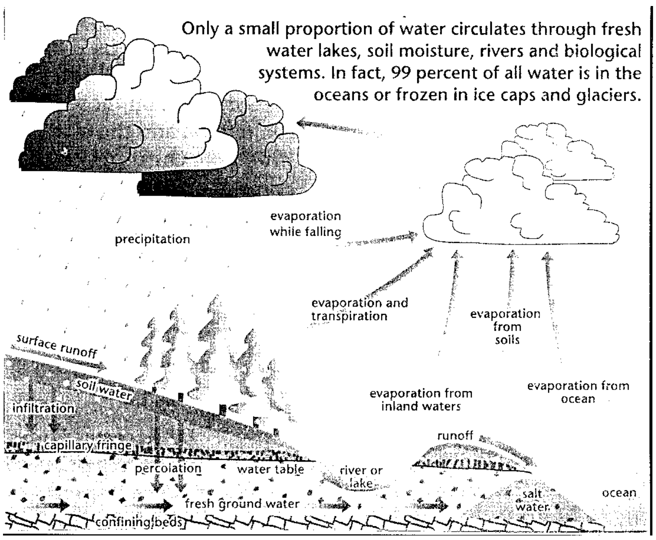
Indicators for sustainable water resources development

Information on quantity and quality of natural resources is essential for sustainable agricultural development. In particular, information on freshwater resources, their availability and use is becoming increasingly important with the emergence of regional water shortages and the need to improve water use efficiency. This paper discusses the problems met in identifying and computing relevant indicators for sustainable water resources development and presents the current activities of FAO in that field. After a brief review of the main components of the water cycle, the paper focuses mostly on indicators at country level and introduces the relationship between basin and political boundaries as a major issue in computing water resources indicators. A discussion follows about ways to assess water resources and use. A few key indicators are further presented. In conclusion, possible ways to improve future computation of water resources development indicators are discussed.

WATER RESOURCES AND USE IN THE WORLD

FIGURE 1
The hydrological cycle - vital, vulnerable



It is common to consider water resources as that part of the water cycle which runs off in the rivers and infiltrates in aquifers (Figure 1). This corresponds to the part of rain falling over the continents which does not evaporate. By this definition, water resources are renewable, and their value is usually computed on a yearly basis. The global water resources available over the continents are estimated at around 40 000 km^3/yr. Of this volume, only a small part, 9 000 km^3/yr, is considered to be available for use, the remaining part being lost in floods. In 1990, this represented about 1 800 m^3/person/yr available for use. Since estimated average water use

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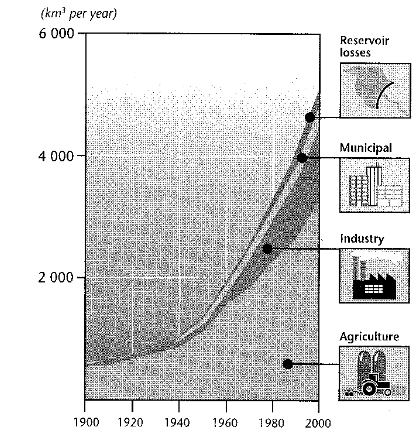
was about 800 m^3/person/yr in 1990, one might conclude there is still plenty of water available for future use.

However, such a conclusion would not take into account the large regional variations of water resources and use, which already lead to severe limitations in several parts of the world, while other regions receive much more than they could use. As an example, central Africa, which represents 18% of the area of the continent, receives 49% of its water, while northern Africa, for a similar area, receives 1.2% of the continent's water resources.

Agriculture is by far the major user of water, with an average 69% over the world, followed by industry, with 23%, and domestic use (cities) with 8%. Yet agriculture is also the sector which presents the lowest return on investment and the highest level of wastage and, in situations of competition, sees its share reduced to satisfy the needs of industries and cities. Figure 2 shows the evolution of water use in the world in the current century, with estimates up to the year 2000, and the dramatic increase in water use which has accompanied population growth and development during the second part of the century.

FIGURE 2
Estimated annual world water use, total and by sector, 1900-2000



ASSESSING WATER RESOURCES

Assessing water resources at country level presents several difficulties. First, a decision has to be made about the kinds of resources which have to be computed. In arid countries, the part of non-renewable water resources (water available from aquifers with a negligible rate of recharge) which is available for use and already being drawn upon for consumption may represent a much larger volume than renewable water resources. Non-conventional resources may also represent an important part of the available water in arid countries. They are, mostly, re-used wastewater and desalinated water. In such countries, water resources assessment simply on the basis of the water cycle is of little use for planning purposes and would only serve as an indicative figure to assess the degree of mining of water resources and desalination.

A second difficulty arises in the computation of surface water and groundwater. Both resources are usually computed separately although they are parts of the same water cycle. Separate computation of surface water and groundwater usually leads to an over-estimate of the global value of water resources in a given area and this error is frequently observed, even in specific water resources studies. Directly related to this issue is the problem of geographical boundaries used in assessing water resources. In order to maintain the integrity of the water cycle, surface water has to be computed on the basis of river basins, while groundwater has to be assessed on the basis of groundwater basins (aquifers). These basins rarely have the same geographical extent, especially in arid countries, and they almost never correspond to political boundaries.

Although water resources are usually expressed on an annual basis, and compared with yearly demand, large seasonal variations can be observed, and can substantially reduce the amount of water actually available for use. In countries where agriculture heavily relies on water resources during the dry season, water availability may be significantly reduced if no storage capacity is available for regulation of wet-season flow. Arid and semi-arid countries are also subject to large inter-annual variations of rainfall and water resources, a variation which has to be taken into account in assessing which part of total water resources is really available for use.

Most of these considerations have important consequences in terms of mapping applications. Figures 3 to 6 show how the problem of geographically representing water resources has been addressed by different approaches. It should be noted that none of these maps really allows the user to assess the water resources in a given location.

TABLE 1
Estimated net consumption rate for different water use sectors

Sector	*Consumption rate (%)*
Agriculture	*60-90*
Domestic use	*5-10*
Industries	*5*
Fisheries	*0*
Recreation	*0*
Environment	*0*
Navigation	*0*

A further complication lies in the concept of available water. It was noted above that river runoff is not fully available for use because of seasonal variations and the presence of floods. Additionally, part of the water flowing into a neighbouring country may be reserved by treaty or agreement and thus cannot be considered available for use in the upstream country. The availability of groundwater is subject to the country's capacity to extract the water. In summary, the concept of availability, which is much more powerful than that of water resources, can hardly be applied systematically over all countries and has strong economic and political implications. Most of the limitations described above apply with a much higher intensity in regions where water is scarce, which are those regions where water resources present a limitation to development.

ASSESSING WATER USE

A distinction should be made between water use and withdrawal. The figures presented previously refer to physical withdrawal from a water source, be it a river, a lake or an aquifer. They correspond to gross withdrawal. In fact, only a part of the water withdrawn is actually used, the rest being lost in conveyance systems or returned to the water cycle after use (return flow). Consumptive use is that part of the water which is lost and does not return to the system (it is evaporated or transpired in the production of biomass). Table 1 gives estimates of net consumption rate for the major water use sectors (Margat, 1996).

Table 1 shows that a distinction must be made between sectors showing a certain rate of consumption (agriculture, industries, cities) and sectors using water without significant physical consumption (aquatic life and environment, recreation, navigation). Although it is generally recognized that these sectors may be of major importance in the overall water balance of a region, for practical reasons they are usually not taken into account in the physical computation of water use. When working at a detailed level, these requirements can be taken into account in determining, for instance, a minimum level of water flow to

FIGURE 3
Mapping mean annual runoff (Korzun et al., 1974)

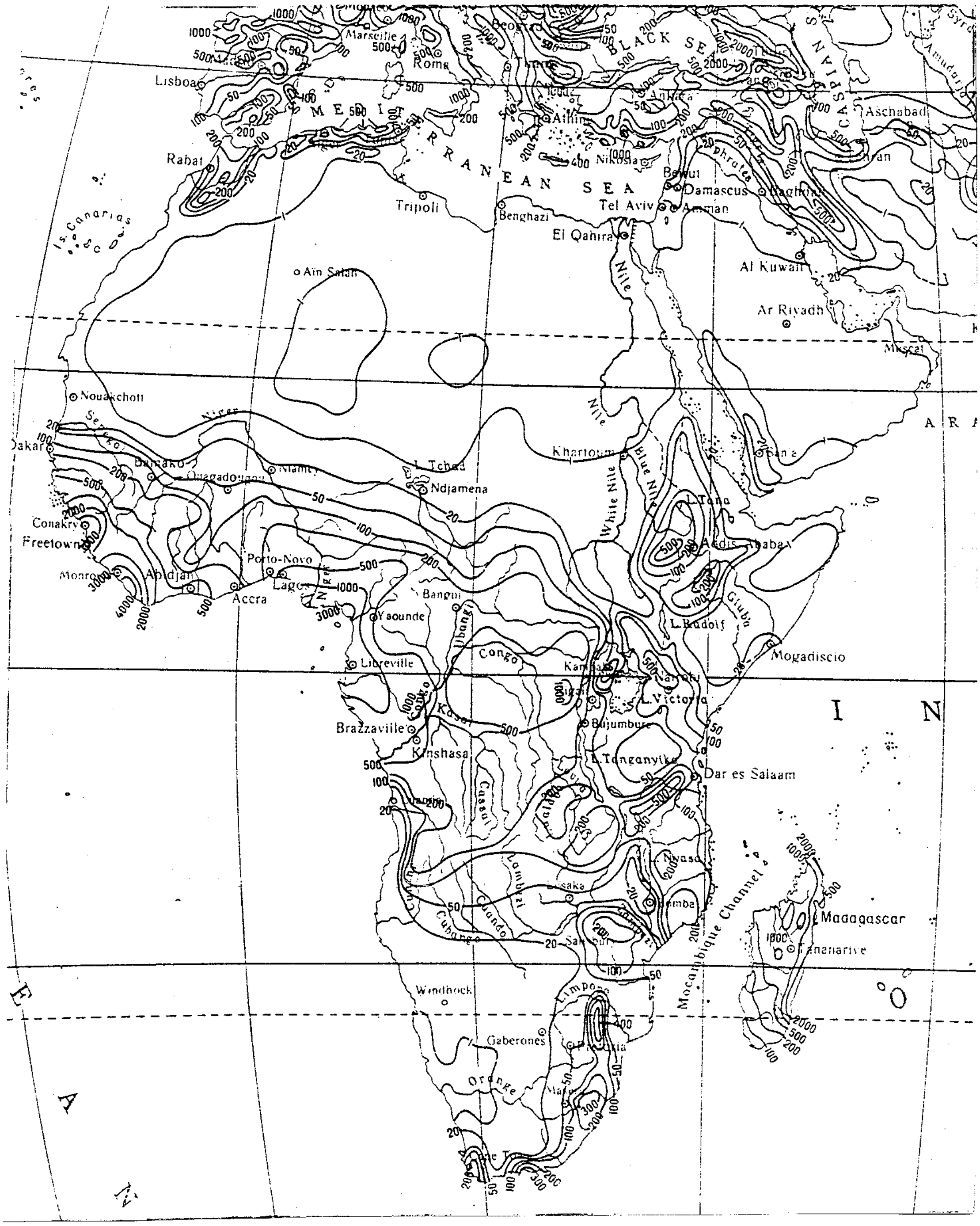
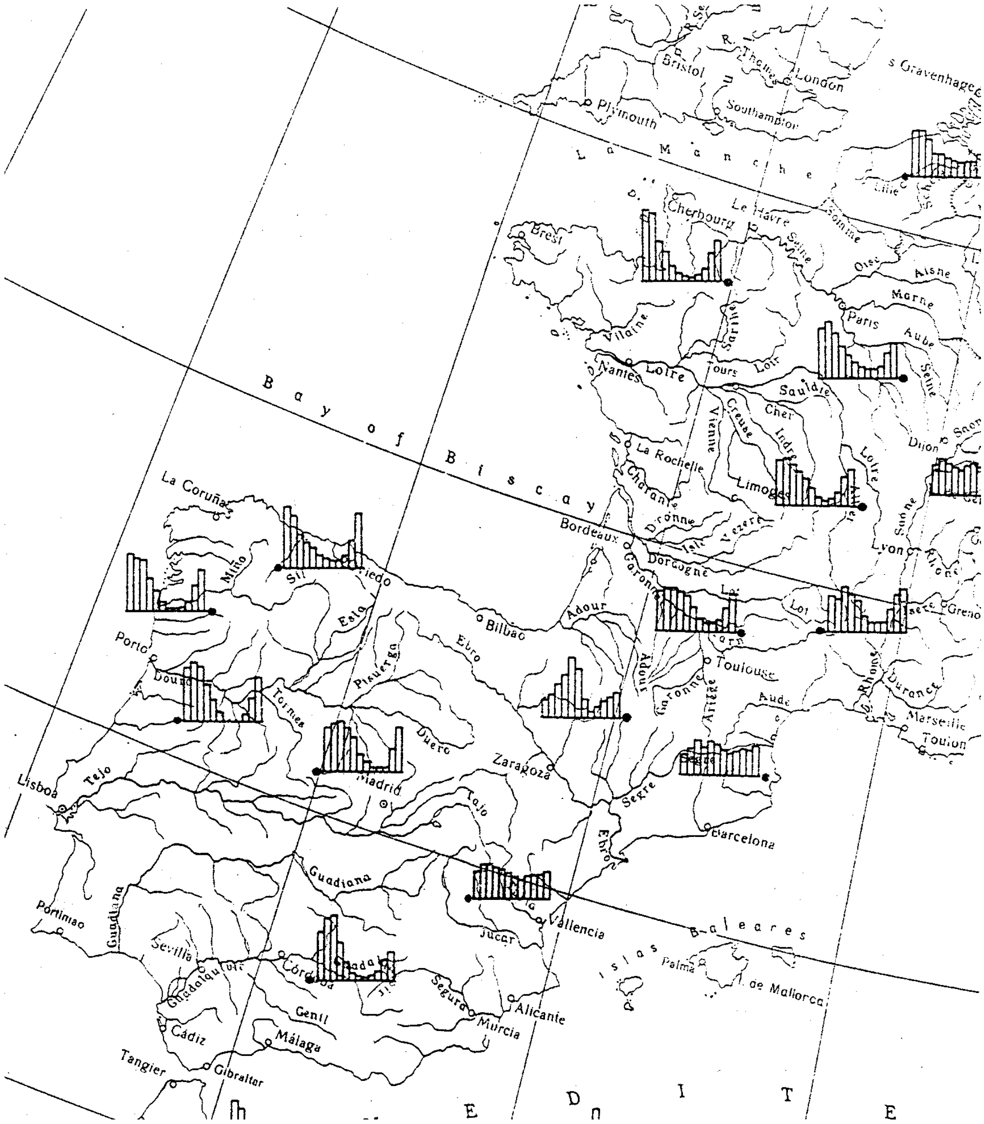


FIGURE 4
Mapping seasonal flow regime (Korzun et al., 1974)



be kept available in the rivers. At country or continental level, however, such an approach is not feasible. This restriction represents a serious limitation to the value of water use figures aggregated at country level.

Even when using gross water withdrawal as a measure of water use, several limitations still exist. Agricultural water withdrawal is very rarely measured. Most of the time it is estimated on the basis of irrigated areas and crop water requirements, with a rough estimate of conveyance losses. Errors up to 100% at the level of a country have been observed for the agricultural sector. For important industries, and large cities, accurate values are usually available on the basis of the capacity of the distribution networks, but in most cases withdrawal must be indirectly assessed on the basis of population or type of industry.

FIGURE 5
Mapping mean annual runoff (Source: USGS)

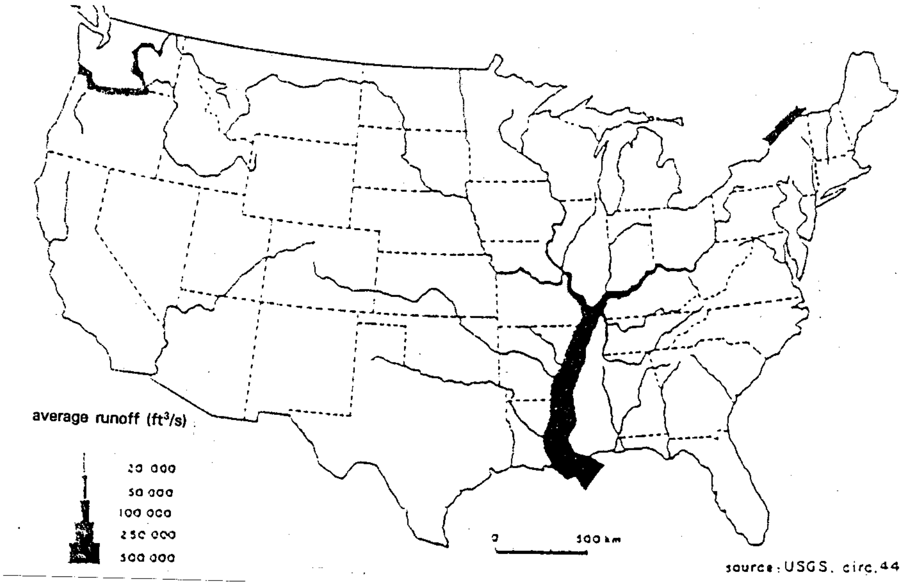
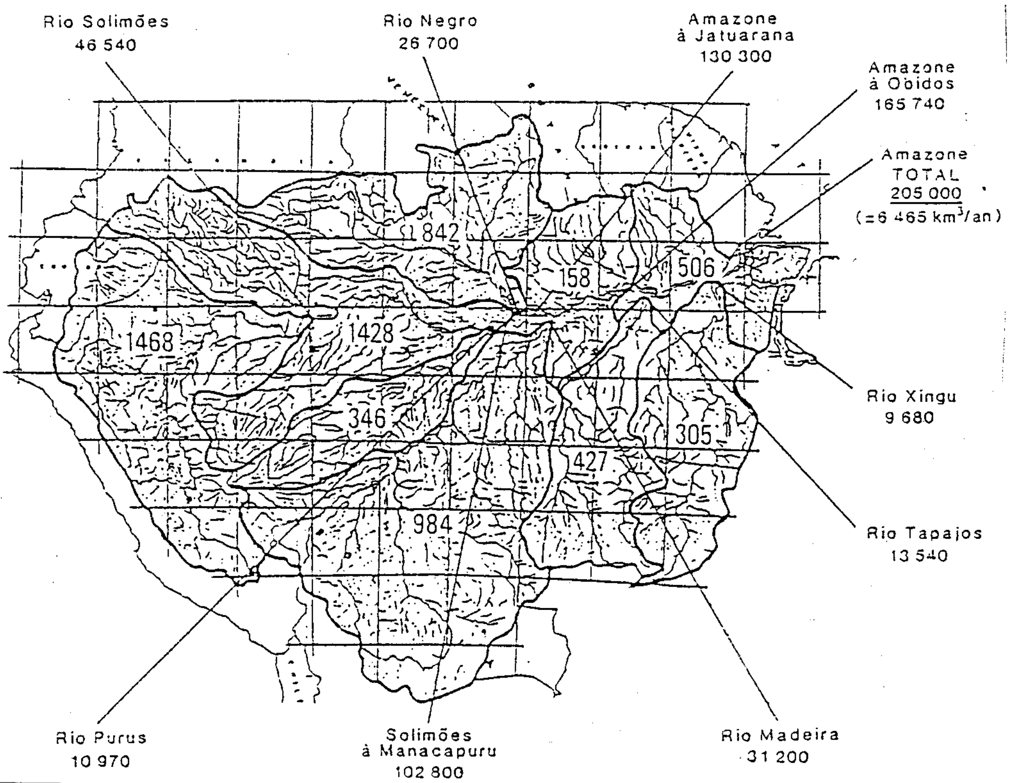


FIGURE 6
Sub-basin representation of water resources (in m³/s)



Another major limiting factor which is difficult to take into account at the level of a country is the quality of return flow. Industries, cities and agriculture usually do not preserve the quality of water in the return flow, and this has important consequences in terms of availability of quality water downstream. Still, the variety of situations makes it impossible to quantify this aspect of water development adequately.

SOME POSSIBLE INDICATORS

All the restrictions described above make the identification of relevant indicators for sustainable water resources development particularly difficult. The uncertainty in assessing resources and use requires the selection of robust indicators. There is no doubt, however, that the relative availability of water resources and human pressure on the resources will be key factors in assessing sustainability in water use. A few indicators which are considered to best represent the overall status of a country's water resources development are presented below.

- *Internal renewable water resources*. This is the average annual flow of rivers and groundwater generated from endogenous precipitation, after ensuring that there is no double counting. It represents the maximum amount of water resource produced within the boundaries of a country. This value, which is expressed as an average on a yearly basis, is invariant in time (except in the case of proved climate change). The indicator can be expressed in three different units: in absolute terms (km^3/yr), in mm/yr (it is a measure of the humidity of the country), and as a function of population (m^3/person per yr).

- *Global renewable water resources*. This is the sum of internal renewable water resources and incoming flow originating outside the country. Unlike internal resources, this value can vary with time if upstream development reduces water availability at the border. Treaties ensuring a specific flow to be reserved from upstream to downstream countries may be taken into account in the computation of global water resources in both countries.

- *Dependency ratio*. This is the proportion of the global renewable water resources originating outside the country, expressed in percentage. It is an expression of the level to which the water resources of a country depend on neighbouring countries.

- *Water withdrawal*. In view of the limitations described above, only gross water withdrawal can be computed systematically on a country basis as a measure of water use. Absolute or per-person value of yearly water withdrawal gives a measure of the importance of water in the country's economy. When expressed in percentage of water resources, it shows the degree of pressure on water resources. A rough estimate shows that if water withdrawal exceeds a quarter of global renewable water resources of a country, water can be considered a limiting factor to development and, reciprocally, the pressure on water resources can have a direct impact on all sectors, from agriculture to environment and fisheries.

Other indicators may further refine the assessment of the water sector. They are related to the seasonal and inter-annual variability of water resources, the degree of flow regulation existing in the country, and a measure of water quality. It would be practically impossible, however, to obtain such indicators systematically for every country.

Finally, an index representing the state of knowledge about water resources and withdrawal could also be developed. It would give a measure of the degree of uncertainty in the values of the water resources development indicators.

PRELIMINARY RESULTS AND PROBLEMS MET

Although assessment of water resources on a country basis is not the primary purpose of FAO's water activities, the increasing pressure on agriculture to reduce water use and wastage in several parts of the world necessitates better assessment of water resources and use, and the development of an information base on the subject. The Aquastat programme has been developed to meet these needs. It is based primarily on information collected at country and sub-country level (FAO, 1995a and b).

By the end of 1995, the survey had been completed for the 53 countries of the African continent. This first exercise made it possible to better assess the availability of information at country level and the results to be expected from systematic country surveys based on existing literature. Main conclusions from the survey are:

; The degree of precision of information on water resources and use depends directly on the importance of water for the country's economy. Arid countries usually have detailed inventories and master plans with very accurate information on water resources and use, while major uncertainties exist in the information on water resources and use in humid countries. This has a direct consequence on the quality of continental assessment: the greatest uncertainty lies in the areas with the largest water resources.

; Many contradictory figures can be found in the literature, showing the degree of uncertainty existing about water resources and use in the countries. Particularly, there is no agreed standard method to compute water use for agriculture. This situation substantially reduces the quality of regional and continental estimates of water use.

CONCLUSION

Further improvement in assessing water resources on a country basis can be expected from extensive use of geographic information systems (GIS). A major effort must be made in the near future to build coverage of major river basins and aquifers. This information can then be used in combination with political boundaries and agro-ecological zones for a better assessment of transboundary water flow. The use of GIS will also make it possible to combine point and area information. In particular, it will make it possible, by integrating point information at basin level, to assess resources in places where measurements are not available.

Action also needs to be taken in harmonizing methods to compute water withdrawal and water use by sector. Of particular importance will be the necessity to agree on a way to compute agricultural water use. A promising experiment was recently made by FAO to assess agricultural water use systematically for the African continent on the basis of irrigated areas and crop water requirements, taking into account climate and irrigated cropping patterns (FAO, 1997).

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Land quality indicators from the viewpoint of inland fisheries and aquaculture

This paper provides a short overview of kinds and characteristics of quality and quantity indicators for inland fisheries and aquaculture and shows how they relate to indicators in other sectors.

FAO OBJECTIVES FOR INLAND FISHERIES AND AQUACULTURE

Indicators have to be viewed in the context of FAO's objectives for inland fisheries and aquaculture. These, very broadly, are to sustain a productive environment for fisheries and for the further development and expansion of aquaculture.

Fishery Indicators

Fairly simple indicators (Table 1) can be interpreted together to reveal the status of fisheries and of fishery resources. For example, artisanal fisheries usually provide from 1 to 2 t/person/year. If the catch per fisher is significantly less, the resources are likely to be over-exploited or the aquatic system is poor in its fish production potential, either naturally or because of human-induced changes. If one directly observes, or has the data to hand to show that gear has been purchased or constructed to catch relatively small fishes and if catch data confirm that mainly juvenile fishes are being harvested, then one can conclude that the resources are being very heavily exploited.

TABLE 1
Some general fishery indicators

- catch/area
- catch/fisher
- gear types and characteristics
- species composition and fish size

Water Quantity as an Indicator of Fishery Potential

Water quantity is a very important indicator of fishery potential, and its variations are indicative of natural or human-induced changes in fishery potential. For example, about 57% of Africa’s large water bodies vary seasonally and inter-annually in their surface area: river floodplains, swamps, shallow lakes and reservoirs (Kapetsky, 1995). Similarly, variations in flows affect both the efficiency of fishing and fishery biological productivity. Models have been developed to predict fishery yields one and two years ahead based on changes in water availability (Welcomme, 1985) and remote sensing technologies are being developed to

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periodically and cheaply measure variations in water surface area in inland systems for predictive purposes (e.g., Travaglia, Kapetsky and Righini, 1995).

Indicators of the "Health" of the Aquatic System

Usually this type of indicator is quantitative in nature and the basic concepts are covered in limnology textbooks while the techniques are in standard texts on water quality measurement (Wetzel, 1975; Alabaster and Lloyd, 1982; APHA, 1989; Chapman, 1992; Hellawell, 1986; Howells, 1994). However, there is a very simple qualitative indicator of ecosystem health: the kinds of fish species present. Generally, the greater the variety, the better the condition of the system in terms of long-term stability.

A few key physical and chemical measurements go far toward indicating the status of the aquatic ecosystem: dissolved oxygen, turbidity and electrical conductivity.

In short, the dissolved oxygen concentration indicates the capability of the water body to support aquatic life, turbidity indicates opportunities for photosynthesis and conductivity (in non-saline waters) discloses the system's richness in nutrients.

Of course, other indicators are routinely used and some require sophisticated and costly equipment for data collection and analysis. The choice of additional indicators will depend on requirements to measure perceived changes in a given water body which may be affected by different types of pollution or physical degradation (Barg *et al*., in press; Dunn, 1989; Muller and Lloyd, 1994). For example, the productivity of an aquatic system may be impacted by siltation, or very low concentrations of heavy metals or pesticide residues. Use of the key indicators above would point to a problem. This would have to be identified by additional measurements.

KEY AQUACULTURE INDICATORS

Aquaculture indicators (Table 2) function to measure the suitability of the environment for aquaculture development and, when measurements are made periodically, many of the same parameters are important gauges to judge the sustainability of aquaculture. In employing them, one is matching a culture system (e.g., a pond) and an organism (e.g., a carp or tilapia) to an environment (e.g., family farm or commercial fish farm).

TABLE 2
Key general indicators for aquaculture development

; water availability (and water balance)
; land use/land cover
; terrain and soil characteristics
; inputs
; infrastructure
; markets
; weather/climate

The significance of these general indicators is mainly self-evident - they pertain very closely to agriculture development and management. An example of how information created for agriculture can be re-interpreted to assess aquaculture potential at a continental scale is given by Kapetsky (1994).

Among the aquaculture indicators, land use and land cover merit special mention. These can be interpreted for a variety of decisions including those on relative amount of land cover types as they influence water quality, crop types and agricultural by-products as fish feed inputs, and land availability, land acquisition and land preparation costs (e.g., Kapetsky, McGregor and Nanne, 1987).

INDICATOR DATA PROBLEMS

In the realm of indicators for inland fisheries, the necessary data often are not collected for individual water bodies, except the largest ones. Water quality indicators frequently are not synoptic and there can be problems of differing methodologies for the same parameter. Water quantity indicators may not be in useful units of measurement (e.g., water volume in place of water surface). Indicators for all purposes suffer from sporadic and or geographically incomplete coverage.

CONCLUSIONS

- The indicators covered in this paper can be useful for a range of purposes. They may be employed for brief visits to individual sites, or they may be used for geographically broad, long-term studies. Remote sensing can be an important tool for data acquisition for the latter and geographical information systems are increasingly used to evaluate the indicators when taken together.
- Generally, indicators useful in other sectors, notably agriculture, can be used directly, or re-interpreted, for fishery and aquaculture purposes by selecting different thresholds.
- For inland fishery resources and for aquaculture, key water indicators can be relatively simple, but they have to be dynamic (i.e., measured frequently.
- Frequency of observation should take into account seasonality and the rate or frequency of land and water use changes in the river or lake basin.
- Water quantity or surface area is a vital indicator for fisheries and aquaculture.
- Land cover (or better, land use) is a key land indicator from which much can be inferred about water quality and availability of land and water for fisheries and aquaculture.
- More sophisticated indicators can be useful, but continuity of coverage over large areas with simple indicators is more useful than geographically and temporally spotty coverage.

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Indicators for sustainable development of fisheries

Following the work of the World Commission on Sustainable Development and the Brundlandt Report, the issue of using information for more informed planning and decision making has been central to the development debate for all sectors, and particularly for those exploiting natural renewable resources. Following UNCED (Rio de Janeiro, 1992) the issue has gained further momentum and most sectoral and inter-sectoral organizations (including non-governmental ones), policy-making structures and management bodies are addressing the issue (in particular, the Scientific Committee on Problems of the Environment (SCOPE) in cooperation with UNEP). This involves assessing the state of the resources (often bad), addressing social and economic constraints (generally serious) and institutional failure (resulting from ineffective laws and organizations), and discovering the relative inadequacy of the information base and analytical capacity available to support decision making. Information available is rarely sufficient for fully informed decision making and simple and carefully selected indicators could improve the effectiveness of decision processes.

There are hundreds of definitions of sustainable development, leading potentially to a wide range of diverging criteria to define sustainability indicators or to interpret their variations. For fisheries, a useful definition would be the one agreed at FAO in 1988 which states that sustainable development has been defined by the World Commission on Environment and Development (1987) as "*development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*". It has also been defined by the FAO Council in 1988 as "*the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Such sustainable development conserves (land,) water, plants and (animal) genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable*". This definition implies an objective of optimizing welfare from a limited natural resource base, minimizing resource and environmental degradation, and regulating the rate of use of these resources over time. "Welfare" is defined by Shuh and Archibald (1996) as including "*the value of natural amenities, improvement in environmental quality, reduction of pollution and waste, and value of the inter-generational equity*". Pontecorvo and Schranck (1995) refer *to "the welfare goal of maximizing the long-run net economic yield from the resource base"* which would *"eliminate short-run profit maximization.. and incorporates the biological goal of conservation".*

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Paper presented at the 2nd World Fisheries Congress. Workshop on Fisheries Sustainability Indicators, Brisbane, Australia, August, 1996

Dahl (1996) lists some of the many dimensions of sustainability (fiscal, ecological, human, social, moral, ethical, and spiritual), each of which could, potentially, lead to development of indicators.

The concept of sustainability has been embedded in fisheries literature for about half a century at least in the concept of maximum sustainable yield (MSY). This concept has been used for decades as a measure of fishery potential and, unfortunately, sometimes as a development and management target. In the post UNCED era, the general concept requires explicitly that *both* the conditions of the ecosystem and the people living in it be either "good" or improving. There may be a number of interpretations of "goodness". Prescott-Allen (1996) considers that "*ecosystem well-being is a condition in which ecosystems maintain their quality and diversity and thus their potential to adapt to change and provide a wide range of choices and opportunities. Human well-being is a condition in which all members of the society are able to define and meet their needs and have a large range of choices and opportunities to fulfil their potential. A sustainable society would be able to achieve both conditions as well as (have) the capacity to anticipate change and recover from eventual setbacks*".

THE NEED FOR SUSTAINABILITY INDICATORS

Chapter 40 of Agenda 21 calls for the development of indicators of sustainable development and the first and second sessions of the Conference on Sustainable Development (1993 and 1994) stressed the need for a "Menu of Indicators" as a basis for: (a) establishing cost-effective data collection systems; (b) monitoring conditions and trends in the fishery sector; (c) informed decision making; and (d) as a possible basis for early warning systems.

Sustainability indicators (SIs) are pointers which would be used to reveal and monitor the conditions and trends in the fishery sector. They would allow monitoring the sustainability of the fishery sector and the fishery development policy and management performance in relation to the various components of the fishery system: the environment, the target resource, the associated and dependent species, the economic and social conditions, and the cultural context. Ideally, SIs should look at environmental, resource, economic and social elements of sustainability in an integrated manner.

Indicators could be needed, for instance, by a State to judge whether the owners of exclusive fishing rights are complying with the duty of care imposed on them, or whether a straddling stock or highly migratory resource is exploited in compliance with the Law of the Sea and other relevant international instruments (such as the FAO Code of Conduct on Responsible Fishing). They could also be used by NGOs and the public at large to assess the performance of a national policy or management system. In international trade, and following recent developments, they could also be used as a basis for an eco-certification and labelling system of fisheries and fishery products as proposed by the World Wide Fund for Nature (WWF) and an important worldwide fish trader (Unilever) in the framework of a Marine Stewardship Council.

Indicators could also be used dynamically to compare the trajectory of a fishery with a planned (target) trajectory. For instance, they could be used to compare the evolution of spawning biomass during the implementation phase of a resource rehabilitation strategy with the planned trajectory, taking corrective decisions when the indicator diverges from the target trajectory. Dahl (1996) gives examples of such use for population and pollution indicators.

Many fisheries are studied using complex bio-eco-sociological models of growing complexity and very demanding data requirements. Their results are often very complex and their presentation may vary greatly between models. These results need to be presented to all stakeholders in a simple, readable way. In addition, the information required for complex models is not always available with low data requirements. There is therefore a need for a simple and robust system for tracking instability, through the use of a limited number of indicators with some integrative properties (i.e., the fluctuations of which reflect changes in more than one component of the fishery sector).

The need for indicators creates, in turn, a need to (a) develop more accurate information systems to be updated in quasi real time; (b) develop indicators sufficiently specific to be of practical value for management, and sufficiently integrated and generic to be comparable across fisheries; (c) to integrate the environmental, biological, economic and social indicators into aggregate ones. The development of indicators therefore poses a significant challenge to countries and particularly to their research institutions.

CRITERIA FOR SUSTAINABILITY INDICATORS

In order to be acceptable and effective, indicators and criteria for sustainable development should be relevant, reflecting key forces and properties of the exploited ecosystem as well as sufficiently accurate and precise. To be used for management, they should be based on a large consensus among interested parties, particularly but not only on international fisheries. Such consensus is usually obtained through guiding and binding agreements and conventions, as well as agreed standards and methodological protocols. In this post-UNCED era, and considering the requirement for precaution enshrined in UNCED Principle 15, indicators of sustainability should explicitly take account of the uncertainty in the data and estimation procedures. While general rules may apply, they should also be context-sensitive and adapted to the area and the species concerned. Finally, they should also relate explicitly to management objectives and constraints as reflected in management reference points. These considerations are further developed below.

Relevance, scope, timeliness, accuracy and precision

The prime qualities of any type of information for decision making are: relevance, scope, timeliness, accuracy and precision. It may seem evident that a sustainability indicator should be of direct relevance to the issue of sustainability. It may be less evident that an indicator may not be relevant in isolation and that a combination is often required to ensure such relevance. Total catches, for instance, while generally available, give little clue as to whether the fishery is sustainable or not in the absence of complementary data on fishing effort and species composition. Similarly, data on total fleet capacity (in terms of number of canoes or total Gross Registered Tonnage (GRT) or horsepower) may not really reflect the trend in fishing pressure in the absence of data on the operation of the fleet, particularly its rate of use. Because sustainability is a complex issue involving a number of considerations related to the ecosystem and society, a system of indicators is needed, the scope of which should cover both the resources to be used sustainably and the goods and services obtained from the system as well as relevant societal parameters. In addition, indicators should preferably be unbiased and their trends should really reflect the evolution of the magnitudes they are supposed to represent. They should be estimated with sufficient precision to allow distinction between the main "signal" the indicator is supposed to provide and the residual "noise" related to error in the data or in the system representation (e.g., the assumed cause-effect relationships).

Degree of consensus

As indicators are aiming, *inter alia,* at institutionalizing transparency, they require agreement among those for whose use they are intended. In general, "sustainability" is perceived differently by different users. At national level, indicators of sustainability might be selected and imposed by the government on the basis of its own criteria and objectives. If decisions affecting wealth and its distribution will be made on the basis of these indicators, governments will have to develop consensus around them between ministers and user-groups. *A fortiori,* indicators need to be agreed upon in international exploitation systems for shared, straddling and highly migratory stock. This may become necessary if procedures for eco-labelling and eco-certification of products or management systems are put in place. This implies the existence of an international mechanism to develop such agreement as well as legal texts, agreements and guidelines around which consensus can be developed based on scientific analysis. The existence of a regional fishery body or management arrangement is a pre-requisite. In all cases, an interactive process of development of agreed objectives would greatly contribute to the process of definition of sustainability indicators.

There are a number of important internationally agreed instruments, the provisions of which may or should be implemented in developing and managing fisheries. The central ones are the 1982 UN Convention on the Law of the Sea (UNCLOS) which came into force in 1994, the 1995 UN Agreement for the Effective Implementation of the 1982 Law of the Sea Convention in relation to Straddling Fish Stocks and Highly Migratory Fish Stocks (hereafter called the 1995 UN Agreement), and the 1995 FAO voluntary Code of Conduct for Responsible Fisheries. There are also a number of agreements related to, for example, the marine environment, or to shipping, which might lend themselves to the development of indicators of interest to fisheries.

In order to conform with UNCLOS sustainability indicators should be based on *"the best scientific information available*". This means that the indicators should: (a) be based on accessible and verifiable information, and (b) calculated from a documented and peer reviewed protocol. This also implies that MSY "as qualified by relevant and economic factors" (UNCLOS Article 61) should be used as a benchmark (but not as a development target). In many instances, in order to facilitate comparative approaches among fisheries and areas and in order to ensure stability of the indicator with time, conventions might need to be developed agreeing formally on the data to be used, the criteria to be followed, and the derivation methodology, establishing the indicators as international standards.

To facilitate agreement, selected indicators should be accompanied with detailed information concerning: (a) type of indicator: pressure, state, or response indicator; (a) purpose of the indicator; (b) relevance to policy; (c) relevance to sustainable development; (d) linkages with other indicators; (e) targets; (f) related international conventions and agreements: identifying the commitment; (g) data requirements; and (h) appropriate methodologies.

Precautionary character

Recognizing the level of uncertainty in the scientific understanding and data, sustainability indicators should also reflect a *precautionary approach* to fisheries as required by UNCED (Principle 15), and foreseen in the 1995 UN Agreement and the 1995 FAO Code of Conduct. Indicators should be developed taking into account the available guidelines for the Precautionary Approach to Fisheries (Garcia, 1994; FAO, 1995, 1996). This implies that the indicators and criteria should be selected and estimated in a way that explicitly takes into account their uncertainty (e.g., by estimating their confidence intervals, using precautionary criteria), and minimizes risk for the resource and the people. Precaution should also be reflected in the management set-up, the characteristics of which could be used as "institutional" indicators of sustainability (see the section below on "Indicators of structure"). For instance, a precautionary management strategy should incorporate continuing collection of appropriate data and have sufficient flexibility to allow a quick effective reaction to any signs that something is going wrong. A fishery solely regulated through total allowable catches with no control on fishing capacity would be less precautionary than a fishery based on strict controls in capacity and quantitative fishing rights. The subject is elaborated further below.

Specificity

While a number of potential indicators are probably of general use, particular characteristics of species, stocks or fishing areas affecting resilience of resources or fisheries sustainability should be taken into account as well. This could be done by using different indicators for different types of resources (e.g., birth rate for marine mammals, spawning biomass for sardines) as well as different criteria to indicate the boundaries within which the indicator is allowed to fluctuate (e.g., the minimum allowable reproduction potential would be set at a higher level for whales than for sardines). This latter device would be useful in increasing the level of precaution for particularly sensitive, endangered or unstable species. Indicators should also take account of the local socio-economic conditions and traditions.

Linkage with management objectives and reference points

Fisheries scientists and management have been using indicators and criteria of sustainability for a long time even though the terminology was not in general use. For example, catch rates, stock biomass, recruitment levels, costs, revenues, etc. are traditionally calculated (and often standardized) in fishery science and can be related to sustainability. There are many possible sources and types of indicators in fisheries, but the interpretation of their fluctuations in terms of sustainability will depend totally on the criteria used to set allowable limits to these fluctuations.

In seeking criteria for sustainability of a fishery, it is essential to examine the management objectives which have been designed for sustainability. These are the first place in which the principles for sustainable fisheries should be reflected, demonstrating at least the intention of meeting sustainability requirements. Making a judgement on objectives requires that they are explicitly stated, and in a sufficiently quantitative manner to allow performance evaluation. In practice, explicit statement of objectives are rare and in most cases they are expressed as "motherhood" statements, not permitting any objective assessment except perhaps on the long-term and in retrospect.

Fishery management objectives indicate the limit towards which the fishery is aimed and indicators can be developed (and usually are) to monitor the performance of the fishery in relation to them. However, these could only be considered as "sustainability" indicators if the objectives themselves have been selected with sustainability in mind. For example, the evolution of annual catches in relation to a fixed total allowable catch, or to MSY, would not tell much about the sustainability of the fishery in the absence of effort data. In addition to production targets, fisheries should have conservation objectives, expressed as targets or constraints, and the indicators should show the state of the fishery in relation to them as well as the rate at which they are evolving towards or away from them. Conservation *targets* exist when management aims at them (e.g., within a rebuilding strategy). A conservation *constraint* exists when, for example, a minimum biological limit (considered "safe" for the resource) is set. In this case indicators should show that the fishery does not cross this limit.

Management reference points are of general use in fisheries to reflect objectives (Target Reference points, TRPs) or constraints (Limit Reference Points, LRPs, and Threshold Reference Points, ThRPs) and would be essential criteria for sustainability, delimiting the allowable area of fluctuation of the indicators. The use of management reference points and their role in relation to precaution are discussed in Caddy and Mahon (1995), Garcia (1994, 1996), and FAO (1995).

NATURE AND TYPES OF INDICATORS

Fishery sustainability indicators (FSIs) should be selected for their ability to indicate whether a fishery is sustainable (responsible) or not. However, there are many requirements for sustainability and therefore many potential indices of sustainability based on the structure of the fishery system and its performance in relation to agreed criteria.

Weak and strong sustainability

In selecting indicators and establishing the criteria by reference to which performance will be assessed, it may be convenient to refer to definitions of sustainability as a starting point. There are many definitions, some of which differ fundamentally, for example the concepts of "weak" or "strong" sustainability. Weak sustainability allows full substitution among all forms of capital (natural, economic and social) and would allow depletion of the natural capital provided the sum of all three is kept constant for future generations or increases over time. Strong sustainability, on the contrary, assumes that forms of capital are not interchangeable and should be conserved separately. This implies that fisheries resources should not be depleted beyond their natural capacity of renewal and passed as such to future generations. This is in line with the concept of sustainable yield enshrined in UNCLOS and indicates that, for fisheries, indicators should reflect and aim at a form of strong sustainability. In practice, a compromise between the two is chosen based on the concept of acceptable levels of impact.

A system of indicators

The FAO Council definition of sustainable development given in the introduction might be an acceptable starting point to identify issues and indicators. The definition refers to the need to control:

1. the resource base;
2. technological change; and
3. institutional change.

It further stipulates that such controls are needed to ensure:

1. satisfaction of human needs for present and future generations;
2. conservation of land, water, plants and animal genetic resources;
3. non-degradation of the environment;
4. use of appropriate technology;
5. economically viable exploitation; and
6. socially acceptable situations.

Based on this definition alone (and there are many others), indicators, each of which may integrate more than one variable, would be needed to track:

1. the resource endowment, including its abundance, diversity and resilience;
2. the environment, for example by reference to its pristine condition;
3. the technology in terms of capacity as well as environmental-friendliness;
4. the institutions, e.g., fishing rights, enforcement system;
5. the human benefits, e.g., food, employment, income;
6. the economics of exploitation, e.g., costs, revenues, prices;
7. the social context, e.g., social cohesion, participation, compliance.

Indicators of pressure, state, and response

There are many potential indicators that could contribute to track sustainability and, in order to avoid dispersion and overloading of the information collection system, a small number of them will need to be selected. The selection should be issue driven, focusing efforts on:

1. ***indicators of pressures*** (direct and indirect) or driving forces affecting the resource system;
2. ***indicators of the state*** of the system being affected; and
3. ***indicators of response*** reflecting actions taken (by management, or industry, or other stakeholders) to mitigate, reduce, eliminate, or compensate for the stress. Such action could be taken to affect the pressure (mitigation, regulation) or the state (compensation, rehabilitation).

These three types of indicators characterize the *pressure/state/response framework (PSR)*[1] for which examples are given in Table 1.

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1 Sometimes also called the driving force/state/response framework.

TABLE 1
Examples of indicators of pressure, state and response

Issue	Pressure (driving force)	State (Condition)	Response (Mitigating action)
Overfishing Economic losses	Overcapacity	Biomass < MSY Low catch rates Overcapacity	Limit access Reduce effort Suppress subsidies
Littoral habitat degradation	Coastal trawling	% seagrass cover Juveniles mortality	Protected areas Closed seasons Increased penalties
	Extensive aquaculture (and other pressures)	% of mangrove cover	Mangrove replanting Decrease access
Algal blooms	Pollution	Nutrient load Frequency of crises Algal productivity	Aquaculture feed - management Control of LBS[1]

[1] Land-based sources of pollution.

When considering indicators (of pressure, state or response) it will be essential to consider the *linkages* between them (e.g between two pressure indicators or between a pressure and a response indicator) as well as the *response time* (or inertia) of the system, i.e., the time required for a pressure or a response to be fully reflected in the state. Both relate to the dynamics of the resource and the exploited sub-systems and their components. They do not seem to be well represented in the PSR concept which seems to relate better to the long-term e.g. when addressing long standing issues, in which pressures have been exerted for a long time, leading to a chronic "state of nature" reflecting a degree of dynamic equilibrium between pressures, responses, and state[1].The PSR concept captures neither the direction of the trend in the pressure and state and their rate of change, which are fundamental, nor the lag time between the moment the pressure is applied (or changed) and the moment at which the effect is fully reflected in the state.

In practice, it may not always be simple to distinguish between indicators of "state" and indicators of "pressure" and some indicators could be considered either way depending on the particular point of view. Catches, for instance, are an indicator of the level of extraction (a pressure) as well as of the resource (a state). Salaries could be taken as reflecting a state of human well-being or a pressure inasmuch as they could reflect the incentive to fish. Another example is given by the demand for fish. Its increase is a sign of human well-being as well as a potential signal for increased pressure to fish.

Indicators of level, change and structure

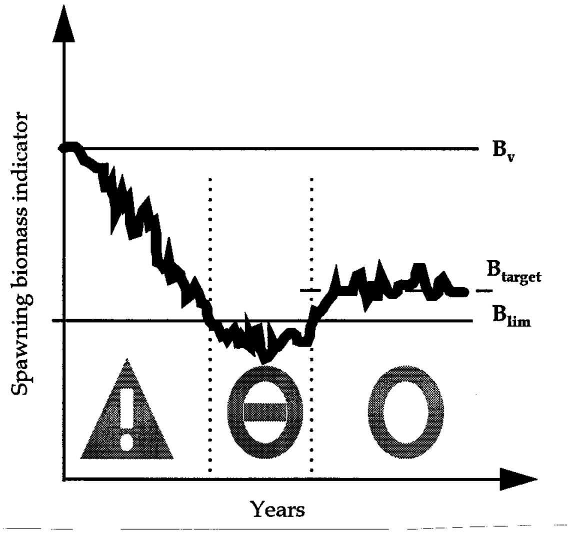
The situation of an exploitation system in terms of pressure, state or response can be more comprehensively described by indicators of level, change and structure.

Indicators of level reflect the spatial or temporal evolution of key system variables expressed as absolute values (e.g. fishing capacity, spawning biomass, revenues, employment, number and gravity of conflicts) or in the form of ratios (e.g., between virgin and present biomass, or between fishery and agricultural revenues). They measure the final

[1] In complex bio-socio-economic systems, it is unreasonable to assume “equilibrium” *sensu stricto*.

response of the system or of one of its components. They integrate a large number of interactions and reflect directly the performance of the system, if used in conjunction with peer-established *sustainability criteria*. However, indicators of level (e.g., stock abundance), in isolation, may not provide information on whether the system is stable, improving or worsening, nor on the action eventually required (e.g. on Monitoring, Control and Surveillance (MCS)? On licensing system? On capacity controls? On market prices or taxes?). Types of such potential indicators are listed in Appendix 2. The example in Figure 1 illustrates the theoretical changes in spawning biomass under fishing pressure, decreasing from the virgin level (Bv) to the lowest allowable limit (Blim) and below, to raise again through management (e.g., effort reduction) to the target level fixed in a management plan. The figure illustrates the fact that the situation requires attention as soon as biomass decreases and becomes unacceptable, requiring corrective action, when biomass is driven below the agreed limit.

FIGURE 1
Theoretical representation of a level indicator (of spawning biomass) and its fluctuations under varying fishing pressure in relation to limit and target levels. Bv = virgin biomass, Blim = minimum acceptable (safe) limit.



Some indicators may not be unequivocally interpreted, however. For instance, high rates of legal action and conviction in a fishery could indicate an active enforcement system which is an element favourable to sustainability. However, they could also indicate a high level of non-compliance which is a serious sign of non-sustainability even in its weak form.

Indicators of change indicate the direction and rate of change of key indicators. Combined with indicators of level, they give a dynamic perspective to otherwise static indicators and would be particularly needed for early warning systems. Dahl (1996) refers to "*vector indicators, showing the direction of speed and movement towards or away from a goal*".

Indicators of structure refer to the functional elements of the system. When referring specifically to institutions they have been called *institutional indicators*. They could be considered as conditions which are necessary for sustainability but which, *per se* may not be sufficient to guarantee it, the final outcome depending on effectiveness of implementation. Nonetheless, the sustainable (responsible) nature of an exploitation system, management set-up, or development strategy can be assessed against a checklist of desirable and undesirable system properties relating, *inter alia*, to: (1) the objectives retained for development or management; (2) the management planning process with its institutions, and mechanisms; (3) the management approach and measures; and (4) the management implementation.

Regarding the *objectives* which should be clearly specified, sustainability should be the long-term overriding objective in a set that should address minimum requirements for resource and environment conservation as well as sectoral production targets. For example, a fishery system aiming at taking two-thirds of the maximum sustainable yield (2/3 MSY) or the maximum economic yield (MEY) would, in principle, be more sustainable than a system aiming at taking the full MSY with the increased risk for the resource that this objective entails.

Regarding the *management planning process and institutions*, elements contributing to sustainability are, for example: (1) the ongoing collection and availability of data and indicators regarding the potential, present state and trends in the environment, the resources, the various fishery sub-sectors; (2) the existence of a coastal zone planning and management system explicitly including fisheries; (3) the establishment of mechanisms to ensure effective people's participation; (4) the existence of dispute resolution mechanisms and qualified voting procedures; (5) the allocation of property or use rights; (6) mechanisms for allocation of wealth; (7) existence of economic disincentives to effectively control overcapacity; (7).the set-up of a high-level independent committee to advise on the development policy in relation to long-term sustainability and oversee its implementation; and (8) a minimum level of fishery research that can support preparation and follow-up of development and management plans.

Regarding *management approaches* and measures, positive signs would include: (1) existence of effort reduction processes (e.g. buy-back schemes) and access regulations; (2) payment for fishing rights commensurate with the value of the resource; (3) regulations on discarding practices, protection of juveniles; (4) establishment of marine protected areas as a means to conserve biodiversity; (5) non-availability or phasing out of subsidies; (6) existence of macro-economic instruments as incentives or disincentives.

Regarding *management implementation*, positive signs would include: (1) a credible control and surveillance system (satellite monitoring, observers on board); (2) an effective system of collection of catch and effort statistics; (3) a streamlined judicial process with deterrent penalties; (4) an in-built process of periodic evaluation of fisheries and management performance coupled with rolling development and management planning processes.

While the above examples referred essentially to the development and management planning processes, other parameters of importance relate to the sector itself, for example: (1) its degree of organization and participation in decision making; (2) its efforts to raise awareness among its people; (3) the quality of the statistics it submits; (4) its cooperation in enforcement.

A much more comprehensive record of structural and process requirements for sustainability is available in the FAO Code of Conduct for Responsible Fisheries (FAO, 1996) which, as an agreed international instrument, and together with its guidelines for practical implementation, can be taken as a basis for assessment of fisheries potential sustainability.

In most cases, these institutional indicators could be considered as "*sustainability switches*" which can be either "ON" or "OFF" . In some instances, however, they might lead to the establishment of a proper level indicator. For example, the ON-OFF switch on "participation mechanisms" could perhaps be turned into an indicator of the level of participation as suggested below (with arbitrary gradations and value judgements):

0.0 - 0.19 = Bad = top-down, non participative system, mere provision of data
0.2 - 0.39 = Poor = people consulted after decisions are made, for comments
0.4 - 0.59 = Medium = people participate in the debate
0.6 - 0.79 = OK = people share some decision power
0.8 - 1.00 = Good = people are involved, including in enforcement.

A matrix of indicators

As an example of the typology given above, a system of indicators in relation to a particular issue (overfishing) would fit into the matrix given in Table 2.

TABLE 2
An indicator matrix

Indicators	Pressure (Capacity)	State (Biomass)	Response (Management)
Level	C > Cmsy	B< Bmsy	Effort reduction scheme
Change	C + 5% / year	B - 4% / year	C - 5% / year for 5 years
structure	3 interacting fleets		Fishing rights

INTEGRATION OF INDICATORS

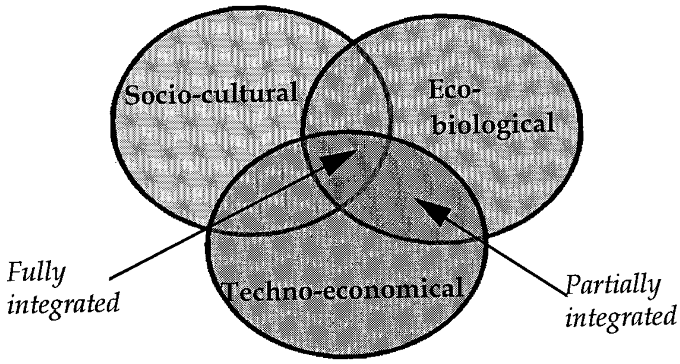
Appendix 1 lists many potential candidates for sustainability indicators, of unequal importance, with non-quantified and sometimes unknown inter-relationships. There would be an obvious advantage to reduce the list to a manageable minimum. It would probably be optimistic, however, to hope that some single indicator could be used to track sustainability. In practice, a number of carefully selected indicators might be needed on the sustainability "dashboard".

Just as objectives, indicators may refer to bio-ecological, environmental, social and economic components. It may be possible and it would indeed be useful and necessary to identify partially integrated indicators, reflecting overlapping components of sustainability (e.g., eco-biological and techno-economic or socio-cultural, Figure 2). A more difficult challenge will be the development of fully integrated indicators, the changes of which would capture the changes of sustainability itself.

It would be useful to elaborate a framework that accommodates the full range of social, environmental and economic factors of the sustainability nexus. The Human Development Index of UNDP is an example of a complex indicator combining per caput GDP, adult literacy, and life expectancy appropriately weighted to give an indicator of living standards. The task appears very difficult however. Fisheries have used sustainability criteria for decades. International agreement was achieved on MSY, its properties and estimation protocols, despite its shortcomings as a criterion, and MSY was enshrined in the 1982 Convention on the Law of the Sea. However, the concept of optimum yield (OY), which was intended to integrate in addition, environment and socio-economic considerations, was never used to any great extent as no agreement could be reached on a universal protocol to estimate it. Instead, the $F_{0.1}$ target reference point (Gulland and Boerema, 1973) has found widespread application because of its simple definition and internationally agreed conventional estimation procedure[1]. This reference point corresponds to lower fishing pressure and costs, and higher spawning biomass and profits than F_{MSY} , at a small cost in terms of employment, bringing the fishery close to an otherwise undefined "optimum".

1 $F_{0.1}$ corresponds to the level of fishing mortality (or fishing effort) at which the marginal yield (i.e., the increase in yield obtained by one additional unit of effort) is 10% of the marginal yield at origin (i.e., observed at extremely low levels of fishing).

FIGURE 2
Schematic representation of the overlapping scope of indicators of ecological, economic and social aspects of sustainability of the fishery system.



This would indicate that there are potentially three ways towards integration of sustainable indicators:

1. determining separate indicators related to resource, environment, economic and social concerns, integrating them in a reference system as proposed for instance by Prescott-Allen (1996) and as illustrated below;
2. formally adopting a single indicator, based on one easily measured variable with recognized "integrative" properties (such as $F_{0.1}$), as a proxy for an "integrated" or "partially integrated" indicator; and
3. a combination of the two.

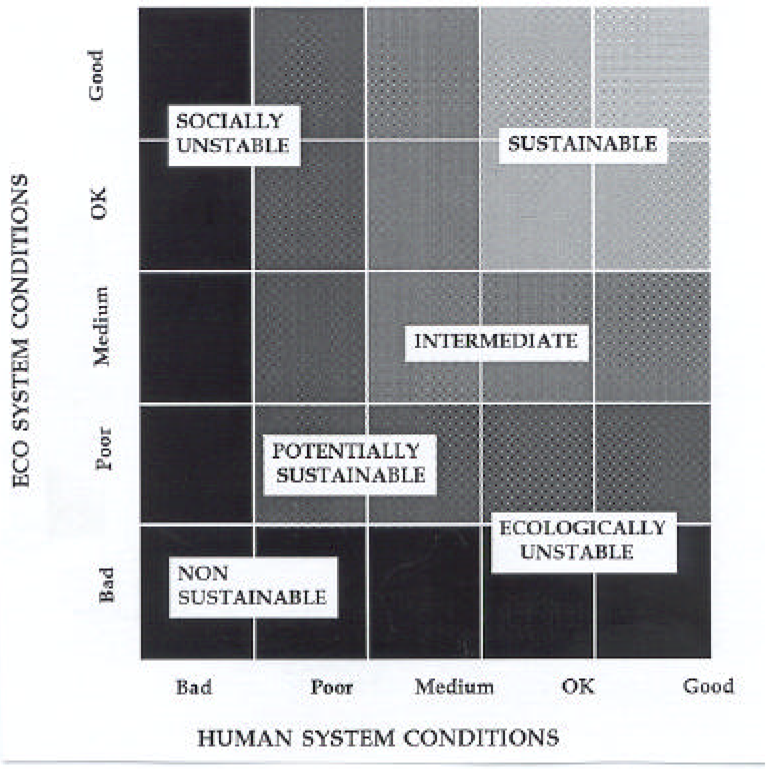
SUSTAINABILITY REFERENCE SYSTEMS (SRSS)

The sustainability barometer of Prescott-Allen (1996)

Prescott-Allen (1996) has proposed a "sustainability barometer" based on a graphical representation of the location of an exploited ecosystem on an orthogonal system in which the two axes represent indexes of human well-being and of ecosystem well-being, considered as the two fundamental dimensions of sustainability (Figure 3). The aim of the barometer is to (a) give a picture of the whole system; (b) treat ecosystem and human well-being as equally important; (c) facilitate a rigorous and transparent progress towards sustainability. Used as orthogonal axes, the human and ecological dimensions, with a scale normalized between 0 and 1, provide an orthogonal system of reference in which the position of an exploitation system (e.g., a fishery) can be located if the corresponding values on the two axes can be estimated.

FIGURE 3

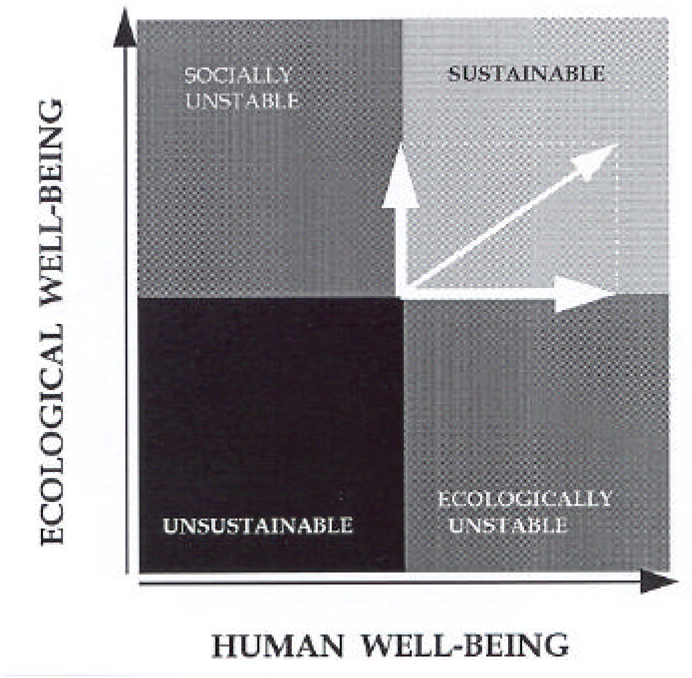
Static representation of sustainability. The Sustainability Reference System (SRS) slightly modified from the "Sustainability Barometer" of Prescott-Allen (1996)



The scales of the barometer include also "value judgements" corresponding to the various intervals on the axes, e.g. the 0.0-0.2 interval is considered "Bad" while the 0.8-1.0 interval is considered "Good". Prescott-Allen stresses the importance of the "scaling" of the barometer and the amount of case-specific judgement involved in it. The paper does not explain how the numerical value of the coordinates is arrived at but examples are given in this paper in the specific case of fisheries. Prescott-Allen called it a "sustainability barometer" used to "measure" exploitation pressure, by analogy with the instrument used to measure atmospheric pressure. Because this device does not provide a "measure" of sustainability but helps representing it, locating an exploited ecosystem in a system of reference, in the rest of this paper I shall refer to it and to other similar devices as "Sustainability Reference Systems" (SRSs).

Figure 3 gives a representation of Prescott-Allen's concept, slightly modified to indicate not only the qualitative sustainability scale but also the areas of social or ecological instability. The conditions expressed in the matrix and the implications in terms of ecosystem or human well-being refer to the long term. It is recognized that, in the short term, a degradation of the ecosystem may help improve people’s well-being. It is also recognized that improving the ecosystem for future generations may require a short-term, temporary decrease in human well-being.

FIGURE 4
The indicator of change. The four quadrants represent the areas of unsustainability (U), sustainability (S), as well as social and ecological instability (SU, EU).



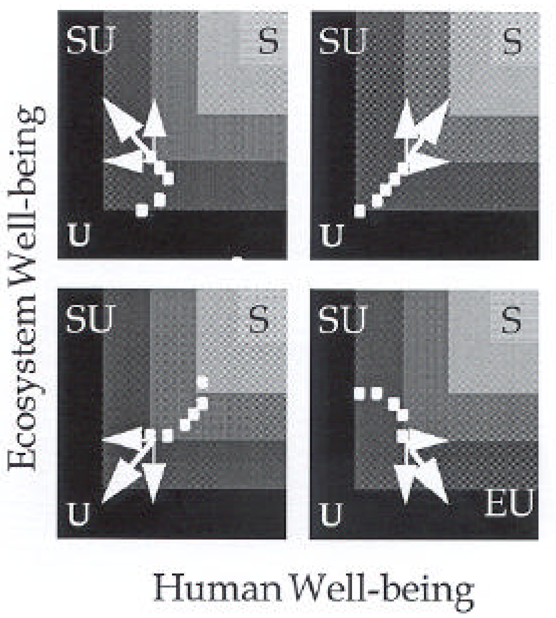
Prescott-Allen indicates that the two scales of the SRS are independent reflecting the fact that the reference system is not a correlation matrix, and stresses that improving one set of conditions should not lead to a degradation of the other - a principle frequently violated in practice. For the same reason, and by design, lower scores always override higher scores (e.g., Good X Bad = Bad) to show that there can be no long-term compromise with bad conditions. This is because bad or poor conditions of either the ecosystem or humans are not considered sustainable, and the condition recognized for the system, by convention, will be the condition of the worse dimension. It is recognized that trade-offs exist between people and is the ecosystem in the short term. In the long term, however, if one dimension is damaged, the whole system is damaged and *"there can be no trade-offs between people and the ecosystem*". On Figure 3, the X and Y scales are identical (i.e., the categories "good", "poor", etc., correspond to the same gradation and type of scale, leading to a symmetric SRS. This may, however, not always be the case. One could imagine that scales could be different, i.e., the same category "good" could cover a different range of the numeric scale on each axis of the SRS, and the scales themselves could be arithmetic or logarithmic, for example.

The concept expressed in Figure 3 is static and falls short of capturing the dynamics of the fishery system. A complete assessment of the degree of sustainability of a fishery should take into account both the static and dynamic aspects of the situation, i.e., position of the fishery system on the SRS, and the local and global trend in such a position, i.e., whether the situation is improving or worsening. It is clear, for instance, that no matter what the static coordinates are, simultaneous decreases in the conditions of ecosystem and humans are a sign of instability and will not be sustainable.

The dynamics of the system could be captured in two ways which could eventually be combined. First of all, once the methodology to calculate the two references (human and ecological) is available, and data permitting, the position could be calculated in retrospect for many years in the past. The sequence of positions on the SRS would "map" the trajectory of the fishery and allow some trend extrapolation. Similarly, if a rate of change (e.g., annual rate) could be estimated in the two dimensions, the resultant of the simultaneous changes would give an indication of the likely future position of the fishery.

Figure 4 illustrates this additional concept. Assuming that a fishery could be located on a SRS, the direction in which (and the rate at which) the situation is changing would be as important as the position on the SRS. Direction and rate of change would indeed provide useful foresight. The combination of Figure 3 and 4 (on Figure 5) would lead to a representation of the fishery system on the system of reference, at the intersection of its aggregated coordinates on the ecosystem and human conditions axes. The dynamics would be captured by the observed trajectory and two arrows, the size and direction of which would reflect the rate of change and its sign (positive or negative). Figure 5 illustrates the importance of adding dynamism to the SRS and clearly shows that for the same position on the SRS, different types of action may be required to correct the trajectory.

FIGURE 5
Dynamic representation of sustainability: combination of the SRS and the IC. The strings of white squares illustrate different "trajectories" of the fishery in the SRS.



It would not be easy in most cases to represent the complexity of the fisheries sustainability equation in a referential system with only two axes, and a more complicated system could be imagined as described below.

A sustainability kite diagram

Star diagrams are often used to represent multivariate properties of a system, e.g., to summarize the performance of a computer with scores referring to its performance in terms of processor velocity, RAM capacity, hard disk capacity, file transfer speed, energy efficiency, interface user-friendliness, etc. Figure 6 gives a theoretical example of such a diagram and illustrates the fact that it can be used to compare the profile (the "signature") of different systems including the "ideal" one with optimal values for all parameters.

A theoretical example of such a diagram for fisheries, using only 4 axes (kite diagram) for the sake of simplicity, is given in Figure 7. The parameters represented are arranged in two domains corresponding respectively to ecosystem and human well-being (in order to remain in the terminology used by Prescott-Allen (1996). Each axis can be scaled from 0 to 1 and the grey scale refers to the assessment categories used in the preceding SRS (black= Bad, light grey= Good). A fishery can be re-presented on this referential system by a polygon and two fisheries can be compared by comparing their polygons. In addition, the position of the polygon in relation to each axis indicates in which sphere action might be required to improve the situation.

FIGURE 6
Theoretical example of a star diagram

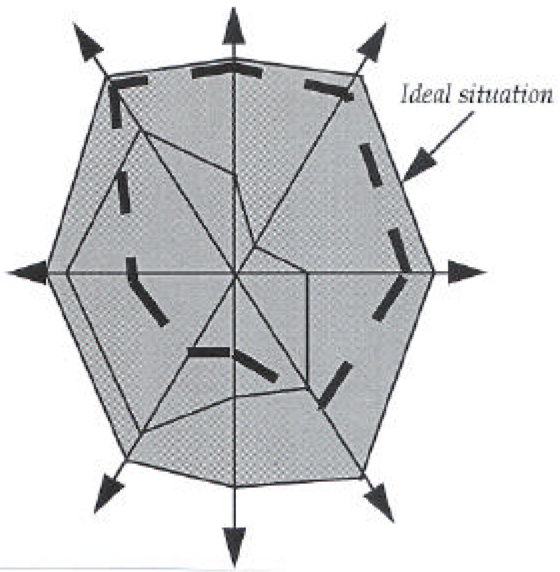
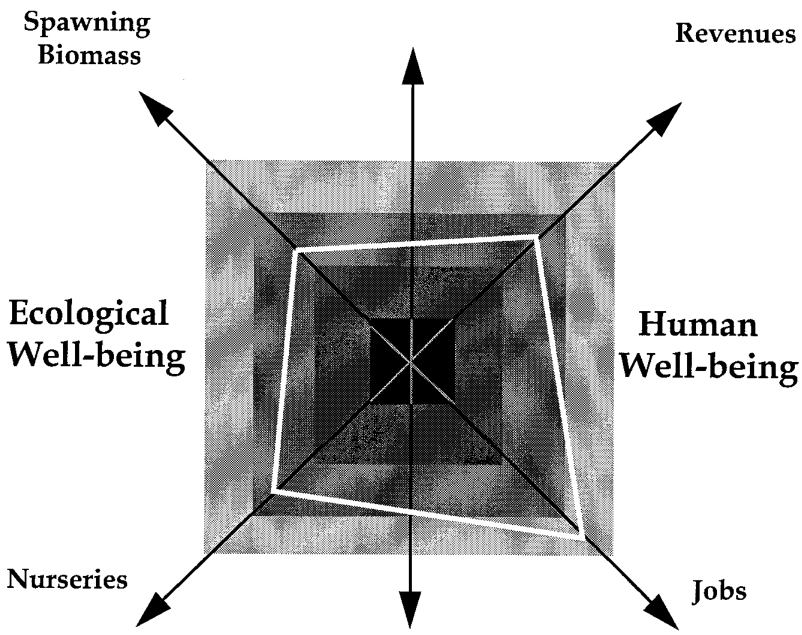


FIGURE 7
Theoretical example of a 4-axis isometric SRS. The situation of a particular fishery is represented on it by a "kite".



Scaling the axes of Sustainability Reference Systems

Prescott-Allen gives a detailed account of many of the problems encountered and options available when scaling the axes of the SRS. Scaling requires the determination of the scale boundaries (0-1 or 0-100) and the relevant subdivisions of that scale according to the value judgements (e.g., deciding whether "Bad" goes from 0 to 0.2 or from 0 to 0.5). The latter could sometimes be arbitrary or conventional, but should in most instances refer to the target and limit reference points. In the example given by Prescott-Allen for the sustainability barometer the two axes are scaled from 0 to 1 and the value judgements (i.e., Good to Bad) are evenly distributed on both axes (cf. Figure 3). In most instances, the true values of the sustainability indicators (e.g., the size of the spawning biomass) will not be between 0 and 1 but, say, between the value of Bv, the biomass of the virgin stock, and zero. In this case, re-scaling will be needed, e.g., by using ratio indicators (e.g., B/Bv). In the section on "Indicators of level", above, an attempt has been made to scale, from 0 to 1, the degree of people's participation in a management system and arbitrary value judgements were given. To use the SRS, the same effort would be required for all potentially useful indicators, using as quantitative methods as possible for the estimates, and a set of criteria for the value judgements. Some examples are given in Table 3 exclusively for the purpose of illustration.

TABLE 3
Examples of scaling of indicators

Scale	State (B/Bv[1])	Pressure (F/ F_{MSY}[2])	Pressure (F/F_{MEY}[3])	Response (Participation)
Good	0.5 - 1.0	0.6 - 0.8	0.8 - 1.0	0.8 - 1.0
OK	0.3 - 0.5	0.0 - 0.6	0.5 - 0.8	0.6 - 0.8
		0.8 - 1.0	1.0 - 1.2	0.4 - 0.6
Medium	0.2 - 0.3	1.0 - 1.3	1.2 - 1.4	
Poor	0.1 - 0.2	1.3 - 2.0	1.4 - 2.0	0.2 - 0.4
Bad	0.0 - 0.1	> 2.0	> 2.0	0.0 - 0.2

1: Assuming a Limit Reference Point at 30% Bv and a Target Reference Point at 50% Bv
2: Assuming a Target Reference Point at F = 60 to 80 % of F_{MSY}
3: Assuming a Target Reference Point at Economic Yield (EY) = 80-100% of Maximum Economic yield (MEY)

The examples given show that the scale may not always be between 0 and 1 and the scaling of the value judgements may also vary between indicators. This last point is illustrated in Figure 8. The value judgements "Good", "Poor", etc. related to the "Participation" indicator, for instance, have been arbitrarily established. Where feasible, and as shown for the other examples given in the table, it would be preferable to relate them to the management reference points corresponding to the desirable (= Good) or undesirable. (= Bad) states of the system components as objectively determined on biological or socio-economic grounds. To reflect consensus, particularly in international fisheries, the scaling of value judgements would have to be agreed among interested parties.

A theoretical but practical example of scaling is given in Figure 9, using two simplistic relationships well known to all fishery biologists and economists: the relationship between a pressure (fishing effort) and two resulting states (the biomass and the economic rent). This figure has the merit of illustrating the fact that:

FIGURE 8
Example of different scaling of value judgements for different elements of the system

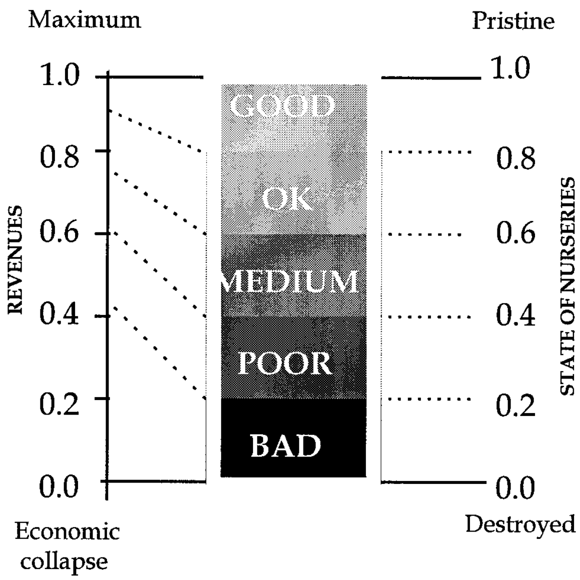
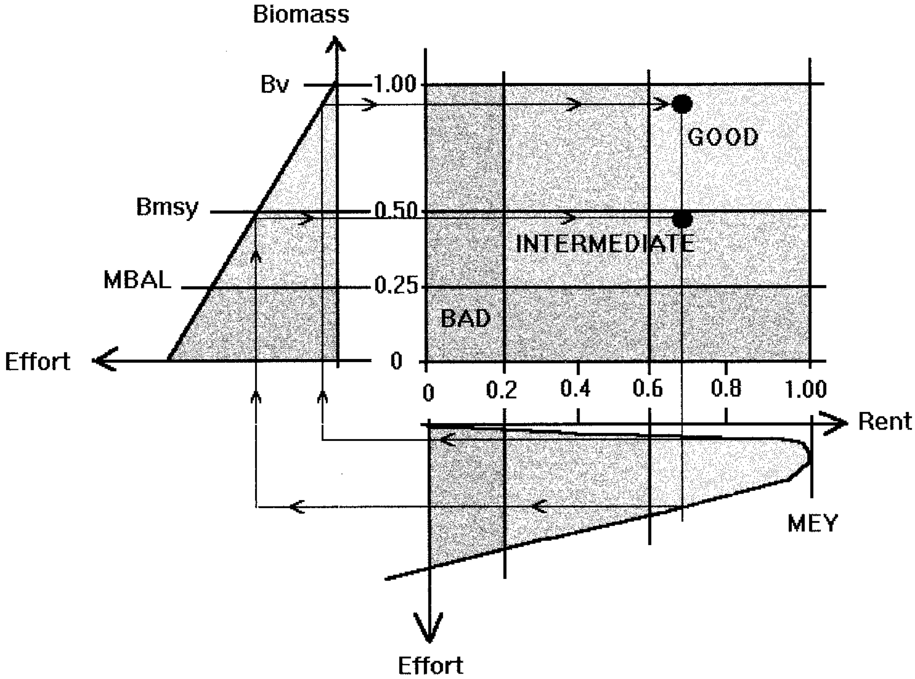


FIGURE 9
Theoretical example of scaling of a 2-axis SRS using spawning biomass and economic rent as measures of ecosystem and human well-being.



1. The functions to be re-scaled may be linear or non-linear.
2. Despite the assumption of independence between the two axes of the SRS, the indicators used may indeed be dynamically and functionally correlated. Action to displace one indicator may also displace the other, sometimes in an unpredictable manner.
3. Because of non-linearity, a value on one axis may correspond to more than one value on the other, with different implications in terms of sustainability and of action required.
4. The reference to standard criteria such as MSY or MEY or B_{MSY} for the value judgements may often lead to dissimilar value judgement scales even though the numerical scale could be identical.

When the axes of the SRS are identical both quantitatively (e.g., both are from 0 to 1) and qualitatively (e.g., on both scales the value judgements correspond to the same range) the SRS could be called "isometric" (as in Figure 7). However, when different scales and particularly different value judgements are used (as in Figure 10) the SRS is "anisometric". Considering that the shading pattern (i.e., the position of the value judgements on the axes) reflects the policy framework (i.e., the set of target and limit management reference points) the anisometric SRS shows explicitly the direction in which the policy is oriented and, in particular, how precautionary it is. It allows therefore for a comparison between policy frameworks as well as an assessment of the performance of particular fisheries - by the position of the fishery kite on the SRS. A comparison between Figures 7 and 10 illustrates the fact that the same fishery kite (i.e., the same set of values for a fishery system) leads to different diagnostics. While in Figure 7 the fishery kite is entirely situated in the Medium-OK area of the SRS, the same fishery appears "Bad" in relation to its ecological axes, in Figure 10, reflecting the fact that, in that SRS, the ecological limits have been set higher.

Scaling and weighting indicators

Combining indicators requires weighting them according to their importance for sustainable development (as agreed by the interested parties). If indicators are averaged into a single value as suggested by Prescott-Allen, weighting is essential and would reflect policy direction by comparison of the weights given to "conflicting" indicators (e.g., of human or ecosystem well-being). In Figure 9, where indicators need not be averaged, it is the scaling of the value judgements which can be taken as reflecting the weight attached to each indicator.

Scaling the SRS and target setting

In the above examples, I have explicitly related the scaling to target and limit reference points. Prescott-Allen underlines that scaling and target setting are two different things and that best values on the scale are not necessarily targets. This is particularly obvious for spawning biomass, for instance, where the "best" value for the stock would most likely be the virgin one (implying no exploitation) while the "best" for fisheries would be some value close to, but higher than the biomass at MSY.

FIGURE 10
Theoretical example of a 4-axes anisometric SRS. The fishery "kite" is identical to the one represented in Figure 7.

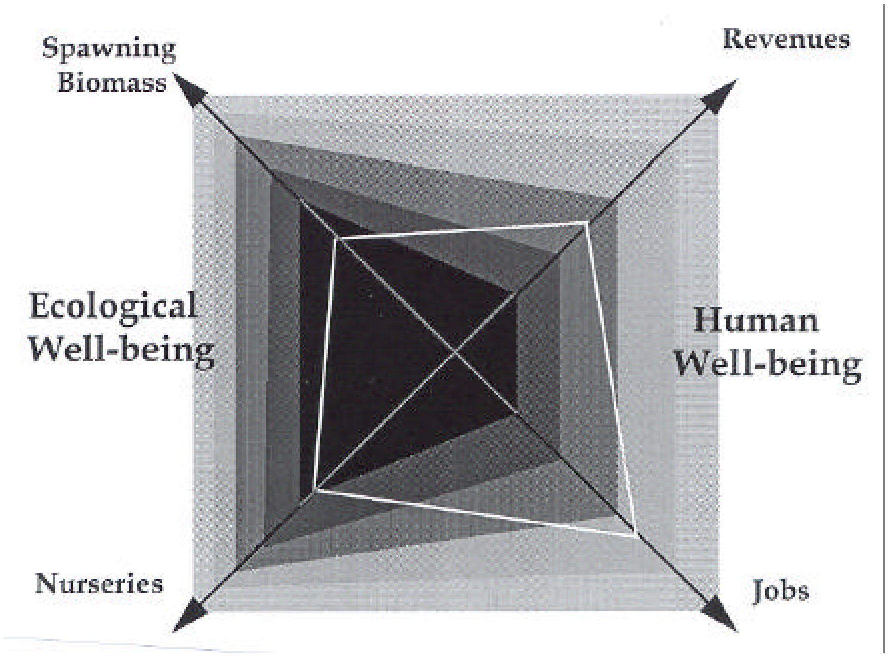
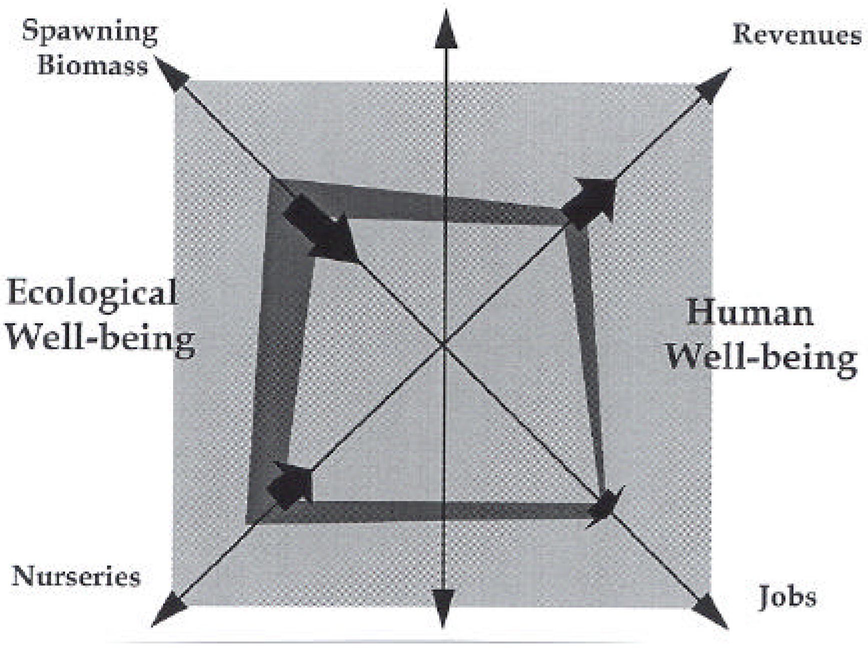


FIGURE 11
Stochastic and dynamic representation of a sustainability kite.



SRS and dynamics of the system

The process of identifying and codifying integrated indicators and of their representation in an SRS will require exploring the relationships between the key variables of the exploitation system. The example given in Figure 9 showed the integration in a SRS of an indicator of ecosystem well-being (the spawning biomass of the target species) and of human well-being (the aggregated economic rent extracted). The figure shows that each indicator is a function of fishing effort (one linear and one non-linear) and that the values of the two indicators are related (even though the SRS is not designed to reproduce this relation). This example shows that:

1. taking action to change one of the indicators will have an impact on the other;

2. one level of human well-being (rent) may correspond to more than one value of the ecosystem well-being (two in the example given) indicating an economic alternative. It is recognized that the alternative also has different implications for human well-being, in terms of employment for instance.

The 4-axis representations given in Figures 7 and 10 are deterministic and static. The addition of confidence limits of the kite and of indicators of change at each of its angles (Figure 11) would give a more accurate and dynamic picture of the situation, indicating the most likely extent and direction of the changes. The ends of the vectors would in fact define the forecast kite. If the indicators of change would be made to reflect the expected impact of governmental policies, the forecast kite would represents a target against which achievements could be compared later on to judge the policy performance, and SRS would be integrated in the management implementation and evaluation cycle.

CONCLUSION AND DISCUSSION

The biological components of sustainability have been familiar to fishery scientists and managers for some time, and are enshrined in the 1982 UNCLOS concept of maximum sustainable yield which must be explicitly related to the conditions of the environmental, resource, economic, social and institutional aspects of fisheries. Despite the obvious complexity of the sustainability issue, the number of parameters that condition it, and the range of potentially useful indicators, there is a need for a simple representation of sustainability by indicators, as integrated as possible. These indicators are intended to complement the sophisticated bio-economic simulations used traditionally in fisheries as a basis for the analysis of management options. They offer a simple way to integrate social considerations, and a generalized representation, explicitly related to sustainability, and allowing comparative analysis and easy access to the information by a large non-technical audience.

Sustainability indicators are also needed to increase the number of system variables effectively used in management and to promote the development of more performance-sensitive management systems than those presently in place - which have demonstrated their lack of reaction to clear signs of failure.

The development of sustainability indicators requires: (1) consensus among interested parties; (2) reference to agreed sets of principles, rules and concepts: (3) standard protocols for their calculation, based on accepted, peer-reviewed scientific methodologies and "the best scientific information available". Indicators should be accompanied by detailed information related to: (1) type (pressure, state or response indicator); (2) purpose; (3) relevance to policy; (4) relevance to sustainable development; (5) linkages with other indicators; (6) targets; (7) relations with international conventions and agreements; (8) data requirements; and (9) appropriate (recommended) methodology.

In fisheries, several important international agreements are available from which the requirements for indicators could be extracted (a task that this paper has not attempted). In this respect, and to underline only one important aspect of these requirements, indicators should reflect a precautionary approach to fisheries and be customized to take account of the nature of the resource, environment or human communities involved. They should also explicitly relate to management objectives and reference points.

Indicators should reflect the "strong sustainability" concept internationally agreed for marine fisheries and enshrined in UNCLOS (with little practical implementation until now!). The indicators on the management "dashboard" should relate to the pressures exerted on the system, its state (i.e., the values of its key variables) and the management response using indicators of level, change and structure. Indicators should provide information on the bio-ecological, environmental, social, and economic components of the fishery system and the challenge is in integrating them as much as possible. The dilemma results from the fact that integrated indicators should be both as general as possible to allow comparisons across fisheries and areas, and as specific as possible to be of practical use in management. This difficult requirement indicates that substantial research should be devoted to the issue.

Sustainability reference systems can be established to compare policy frameworks or management options. Representation of fisheries on SRSs with indicators of change and estimates of confidence limits could give a dynamic representation of its position and evolution in sustainability terms. SRSs could also allow comparison of the positions and dynamics of two or more fisheries, either superimposed on the same SRS (an approach limited by practical complexity of the design) or represented separately on comparable SRSs. It is important to stress (with Prescott-Allen, 1996) that an *SRS "reading is a means to an end and not the end itself"*, that its purpose is to generate debate and serve as a basis for action. In this paper it has been suggested that the SRS be made dynamic and be included as a tool in the management implementation and evaluation cycle.

The main difficulty resides in scaling and aggregation of the potentially available indicators and the scaling of the related value judgements, an area in which achieving agreement is particularly crucial and where both the best scientific evidence and the precautionary approach should play a central role together with considerations of local cultural preferences.

The Pressure/State/Response (PSR) framework provides a way of focusing on the most pertinent indicators even though their potential number remains relatively high. The lack of understanding or complexity of the detailed relationships between indicators (e.g., employment and spawning biomass) and of their quantitative contribution to global sustainability makes the integration a perilous exercise. Hopefully, what is relevant in the SRS is not so much the position of the fishery on the reference as its trajectory with time.

In this respect, a particular difficulty is to be faced regarding the response-time of the system (in terms of "state") to changes in pressure: the amount of inertia inherent in the system should not be underestimated. A representation of transient situations is needed and the indicators of change proposed in this paper could integrate such situations - for example, by representing the present catch per unit of effort as well as the direction and speed at which it is changing due to a management response taken some time ago. The issue is compounded by the fact that biological and economic or social response times are basically different. As a consequence, a management measure or set of measures will have different effects on the various indicators, at different rates, creating potential distortions in the representations.

Much more work is therefore required to test the simplistic representation given by the SRS on particularly well documented fisheries before accepting it generally. An important work is also necessary, at international level, to codify the indicators and the related methodologies and scales before they can become of general use, particularly as a basis for eco-labelling or certification.

ACKNOWLEDGEMENTS

This paper has benefitted from very useful comments of my colleagues Jeff Tschirley and Jorge Csirke to whom I express my most grateful thanks.

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APPENDIX 1

DEFINITIONS

The following definitions apply to this paper and do not pretend to be universally agreed:

Criterion: Condition to achieve some development objective, defined through critical review of scientific information[1] (modified from Calamari and Naeve, 1994). A set of criteria would provide a system of reference within which to assess or judge the state of the exploited system as reflected by indicators.

Indicator: A variable, a pointer, an index of a complex phenomenon. Its fluctuations reveal the variations in components of the ecosystem, the resource or the sector. The position and trend of the indicator in relation to the criteria indicate the present state and dynamics of the system. Ideally, composite indicators are needed, the position and trajectory of which within a system of reference of related criteria would allow simple holistic assessment of sustainability.

Reference Point: A reference point indicates a particular state of a fisheries indicator corresponding to a situation considered as desirable (Target Reference Point, TRP), or undesirable and requiring immediate action (Limit Reference Point, LRP, and Threshold Reference Point, ThRP).

Standard: criterion which has been formally established and enforced by an authority.

[1] In fisheries, and according to the Law of the Sea, criteria would have to be based on "the best scientific information available".

APPENDIX 2

TYPES OF INDICATORS

Fishery-related indicators

Yield-related indicators

Criteria:
Maximum Sustainable Yield (MSY); Maximum Constant Yield (MCY), Long-Term Average Yield (LTAY);

Indicators:
Catches, Catch value, Pelagic/Demersal ratio (P/D), Ratio Yield/MSY, MCY, LTAY, etc.

Capacity-related indicators

Criteria
F_{MSY}, F_{MCY}, F_{LTAY}, F_{MEY}, $F_{0.1}$, F_{OY} (undetermined)

Indicators
Fishing effort (f), Fishing intensity (f/unit area), Fishing mortality (F). Ratios between current and target f (or F): f/f_{MSY}, f/f_{LTAY}, etc. Changes in the ratio between *searching time* and effective *fishing time* could be very symptomatic of changes in abundance. Progressive shifts in fishing areas could indicate resource modification.

Other economic indicators

Criteria:
Economic self-sustainability; Conservation of long-term aggregated welfare potential; Maximum value (?); Maximum rent, Maximum aggregated profit, Subsidies = 0

Indicators
Investment; natural resource valuation scale available; total natural asset value; level of subsidies; ratio of subsidies to capital value; ratio of loans to investment; ratio of present to maximum catch value (?); ratio of present to maximum profit (?); ratio of extracted to maximum or expected rent; poverty, wealth, average age.

Technological indicators

Criteria
Environmentally-friendly gear; highest possible selectivity; lowest possible discard rate or zero-discard option (forced landing); best available and locally affordable technology. Lowest ozone-depleting gas emissions.

Indicators
Existence of Prior Consent (PC) or prior Authorization (PA) procedures. Lists of acceptable gear. Gear regulations addressing selectivity, by-catch of juveniles, and discards (Grid systems, protected nursery areas).

Social indicators

Criteria
Maximum sustainable employment (MSE?); minimum social unrest; equitable (comparable) revenues; acceptable allocation of wealth; safety on board; food security.

Indicators
Coastal populations; employment rate, sectoral emigration and immigration; age; frequency and violence of conflicts, non-compliance index; ratio between fisheries and other revenues; rate of boat and life loss (% loss per year); availability of fish/caput; revenues.

Institutional indicators

Criteria:
Research and decision-support capacity. Specific legislation; Effective peoples' participation. Effective monitoring, control and surveillance; establishment of management committees, allocation of wealth and dispute resolution mechanisms.

Indicators
Research staff and budget. Information systems (e.g., GIS, databases). Contribution of research to decision making and to assessment of management performance. % of fisheries covered by management committees; degree of participation (in information collection, option analysis, decision making, enforcement). Number and role of NGOs. Duration and severity of conflicts (?).

Ecosystem-related indicators

Resource biomass criteria:

Virgin biomass (B_v), Minimum biological limit (MBAL), $0.3B_{v,}$ B_{MSY}, B_{MCY}, etc.

Indicators
Biomass of target and non-target species. Ratios of key variables to target or limit reference point ($B/B_{msy,}$ B/Bv, etc.). Indicators could be fishery-related measures of biomass such as catch per unit of effort (cpue) or independently obtained (such as through trawl and acoustic scientific surveys). Changes in distribution area could be used as a proxy to changes in biomass for small pelagic and some other resources.

Resource demographic structure

Criteria
Lc_{50}, Lm_{50},L , $L_{F=0}$, tc_{50}, tm_{50},t .

Indicators
Length or age composition and average length or age; ratio of average length or age to length or age at first maturity (Lm_{50} and tm_{50}). Ratio of present average length (t) to pristine average length or age ($L_{F=0}$,) eventually simulated with F=0. Sex-ratio where relevant (e.g. marine mammals). School size where relevant (e.g., small pelagic resources). Fat index (e.g., in small pelagic fish used for reduction).

Biological diversity

Criteria
Minimum possible species loss. Minimum loss of genetic diversity.

Indicators
Existence of Protected Marine Areas (PMA). % littoral area protected, totally, partially. Existence of germplasm conservation scheme. Biodiversity index.

***Water quality indicators*:**

Criteria:
"Pristine" conditions or conditions at an agreed reference point in time. Conventional criteria, as established by international environmental conventions, Codex Alimentarius, etc.

Indicators
Transparency (Secchi values); satellite colour scanner indications; Algae index; release of nitrogen components and phosphorates. Other global pollution indicators. Population density (average and seasonal peaks). Absolute values or ratios.

Critical habitats indicators

Criteria:
Seagrass beds, Mangroves, mudflats, coral reefs, "Pristine" habitat area (or, area at an agreed reference point in time), state.

Indicators
Ratio between residual area and "Pristine" or reference area, area of live and dead coral, grass density, species diversity indexes, other indexes of condition.

APPENDIX 3

CATCHES AS AN EXAMPLE OF A SUSTAINABILITY INDICATOR

Type catches: are a response indicator. They relate to the time-related development of a fishery from an undeveloped to a fully developed or overexploited state. Catches describe the main output from a fishery rather than the ability of the resource to provide that output in a sustainable way. As such, catches are very crude indicators of "sustainable use" as they take no account of inputs such as fishing effort and recruitment variation.

Purpose: To monitor the main output of the activity of the fishery sector. In practice, catch data alone are likely to provide only a very crude and unreliable indication of sustainability and so they should be utilized with other information where possible (e.g. on effort, mortality or biomass). However, long data series could be perfectly used to establish retrospective diagnosis of the evolution of fisheries and, by inference, of the present state (see Grainger and Garcia, 1996, for example).

Policy relevance: If catches have been maintained at a fairly steady level for many years during which fishing effort has not increased, it is likely the fishery is sustainable unless environmental conditions change. In the absence of better information, the catch level in such a situation is sometimes used to set a total allowable catch in order to prevent a diversion of fishing effort into the fishery. Catch data for a short time period should never be used as indicators as unusually high recruitment may support a level of fishing in the short term which would not be sustainable in the long term.

Relevance to sustainable development: Irrespective of what other indices are available, catch trends should always be monitored. Declining catches which cannot be explained by factors other than exploitation (e.g., by reduced fishing activity) should be taken as a warning of a possibly unsustainable level of exploitation, and assumed to be unsustainable until such time as more reliable information would become available to indicate otherwise.

Linkages between indicators: In theory, catch per unit effort is an index of stock abundance which can be used to monitor the response of a stock to the development of a fishery. In practice, however, the determination of effective fishing effort is difficult and the relationship between fishing effort and fishing mortality changes as fishing technology develops, with the result that catches alone can sometimes reflect stock abundance as well as catch per unit effort. Combined with other data or indicators, catches can provide useful indexes: for example, the ratio between present and historical maximum, or the ratio between landings of demersal and pelagic species (Grainger and Garcia, 1996).

Targets: Catch limitations are commonly used to control fishing mortality and total allowable catches may be considered targets by industry.

International conventions and agreements: No international conventions propose the use of catches as indicators of "sustainable use" but FAO is mandated to collect fishery statistics from its member countries and to provide summaries. The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982

Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, as well as the Code of Conduct for Responsible Fisheries, state that stock-specific reference points should be applied for this purpose, but that catch and other relevant data on the fisheries should be collected and used to assess the impact of fishing on the resource.

Data requirements: Statistics on landings by fishery and by stock. The catch represents the total removal from a fish stock due to fishing activity. Total catch includes the retained catch which is consumed on board or subsequently landed, the discarded catch as well as incidental deaths resulting from the fishing activity. In practice, however, catch data usually only include the landed component because of data shortcomings.

Methodology: There are no internationally agreed methodologies. Catch data have traditionally been collected through census approaches and are still collected in this way (from vessels records of landings or auction hall records, particularly when catch quotas are used for management). They are increasingly calculated from catch assessment surveys and stratified sampling techniques yielding statistical estimates with confidence limits.

Availability: Catch data, albeit with varying degrees of bias and precision, are usually the most widely available data, at both national, regional and international levels.

APPENDIX 4

MAXIMUM SUSTAINABLE YIELD AS A SUSTAINABILITY CRITERION

Type: Maximum sustainable yield (MSY) is a state criterion and an internationally agreed management reference point, i.e. a point by reference to which the state of the fishery is assessed.

Purpose: Maximum sustainable yield is enshrined in UNCLOS and although no longer accepted as a valid (and precautionary) development target, remains a very important benchmark for management and a minimum target for depleted resources rehabilitation (in the 1995 UN Agreement and in the 1995 FAO Code of Conduct). There are numerous alternative benchmarks at lower rates of fishing (c.f. Caddy and Mahon, 1995; Garcia, 1996) but these are yet to be formally agreed and codified, so MSY remains a necessary universal benchmark. Used in relation with an appropriate indicator of level (such as yield, or effort) it indicates where the fishery system stands in biological sustainability terms.

Relevance to policy: Being enshrined in UNCLOS, MSY is a necessary reference for fisheries policy. The state of the system in relation to the state corresponding at MSY will be one of the key factors in assessing the sustainable nature of the policy. All international fishery agreements, whether legally binding or voluntary require a reference to MSY. MSY is also recommended as a minimum target for resource rehabilitation policies.

Relevance to sustainable development: Although fisheries are sustainable at various levels of development, the risk of collapse (with its related socio-economic dislocations) increases as the exploitation rates (and stress) approach the MSY level and increase beyond it. If a resource biomass is at or below that corresponding to MSY, or if the fishing effort or fishing mortality is at or above that corresponding to MSY, there must be serious concern that the resource may be severely affected and is likely to be overexploited. MSY conditions imply a level of fishing effort in excess of economically optimal harvesting. In addition MSY conditions usually correspond to increased resource variability and uncertainty for the manager and industry, increasing risks and potential costs of error.

Linkages with other criteria and indicators: Determining MSY requires that a time series of catches (another potential indicator) is available. Combined with other indicators, MSY may be used as indicator of level. Where MSY has previously been determined, with its corresponding level of effort (F_{MSY}) and biomass (B_{MSY}), it is possible to monitor the fluctuations of F/F_{MSY}, B/B_{MSY} and Y/Y_{MSY} with time as a measure of performance. Considering that B_{MSY} is usually assumed to be about half of the virgin biomass (Bv), the ratio B/ Bv could provide a closely related indicator when indices are available for both magnitudes e.g. using present catch rates as proxy for B and catch rates at very low fishing pressure at the beginning of the fishery as proxy for Bv. When B/Bv = 0.5 the fishery has reached approximately the MSY level. Although MSY is determined solely on the basis of yield and effort, its position in relation to the maximum economic yield (MEY) is known and limited inferences can be made even though the economic data may not be available.

Target: The MSY concept is a macro-level indicator, irrelevant to individual industry operators but very relevant for governments (in complying with their duty of care) and for fishery management organizations which can use it to develop limit reference points (LRPs) for management (i.e. upper limits to the rate of fishing (or lower limits to the spawning biomass). It is specified in relevant international conventions that when LRPs are approached, action should be taken to ensure they are not exceeded.

Related international conventions and agreements: As mentioned before, MSY is referred to in all international conventions related to fisheries, including UNCLOS, the 1995 UN Agreement and the 1995 FAO Code of Conduct (Article 6).

Data requirements: Unbiased catch data, corrected for discards, as well as stable indices of fishing pressure or fishing mortality. The effort level should be given in standard units adjusted for changes in fleet fishing power over time or changes in geographical extension of the fishery. If reliable time series are not available, contemporary catch and effort data for a number of comparable fisheries with the geographical extension of the stock could be used, assuming equal productivity.

Appropriate methodology: A number of methodologies are available and have been used such as more or less sophisticated surplus production models elaborated by well known scientists such as Schaefer, Gulland, Fox, Pella and Tomlinson (Hilborn and Walters, 1992). The use of composite space-structured models is illustrated in Caddy and Garcia (1982) or Garcia (1984).

Availability: MSY information is available for a large number of resources worldwide. The information available is of very uneven quality and has not been estimated with a uniform methodology. It is rarely given with confidence intervals. The information is often outdated and, with the changes in the ecosystem provoked by fishing (e.g., reduction of predators' abundance), it is sometimes doubtful that available information is still valid. In addition, in areas of high natural variability (e.g., upwelling areas), a long-term average value for MSY is usually not available and would, in any case, be of little use for management.

Session 3

Thematic issues in developing indicators

Land quality indicators: ideas stimulated by work in Costa Rica, North India and Central Ecuador

During 1995, the author was a consultant to three projects which are concerned with soil and water conservation and land management on the farms of resource-poor small farmers. In many cases they farm on (theoretically "non-arable") steeplands:

1. Costa Rica: selected areas in the national joint project (Ministry of Agriculture, FAO and the Netherlands) to promote and apply conservation and land-management practices;

2. North India - Himachal Pradesh/Changar: Indo-German Eco-Development Project in the Siwalik Hills;

3. Ecuador: National Electricity Corporation project for reducing sedimentation of the Paute Hydro-Electric Dam, below Cuenca in the Andean midlands.

In all three, an original project aim could be described as "stopping erosion to limit land damage and as a fore-runner to yield rises". In all three, conventional recommendations for soil conservation have not been enthusiastically adopted, if at all, by the supposed beneficiaries. In all three, land quality is said to be declining, though the evidence for it is based on visual assessment and memory rather than on hard data.

It was clear in all cases that farmers are much more interested in improvement of the existing situation than they are merely in arresting its further decline. Their interests lie in possibilities for improvement of land quality as it affects particularly food security, stability of output and of income. For example:

; In Costa Rica, how land quality indirectly (via soil moisture differences) affects coffee production per ha; how induced changes in soil conditions affect stability of food production in places where rainfall is low on average and erratic in amount and timing; how fertilizer use, affecting chemical quality of the soil, affects the economics of high-value onion production.

; In Himachal Pradesh, farm families are particularly concerned about dry-season water supplies as related to changes in land quality and rainwater absorption; about how land quality may affect the production of grasses, bushes and trees as sources of animal feed; about how fuelwood sufficiency may be affected by land condition.

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; In Ecuador, how improvements in soil-moisture content of the land could maintain yields of tree-fruits for marketing, under unpredictable rainfall conditions; how the "construction" of new soils from weathering rock plus organic materials can increase the usable land surface of small farms; how improvements in land quality could enable higher yields per unit area and greater diversification of marketable types of produce.

In Costa Rica the areas considered are in the process of being settled by in-comers; in the projects in Himachal Pradesh and Ecuador there is out-migration of population in response to both increasing population pressure and to the "draw" of possibilities for wage-earning off-farm.

Within each project's area there are marked agro-ecologic differences which are apparent at the detailed scale of farm-fields, but which would not be readily apparent at smaller map-scales of perhaps 1:100 000. In Costa Rica the project embraces both relatively flat terrain under moderate rainfall, dry steeplands on western slopes, and wet steeplands on eastern slopes of the main divide. In Himachal Pradesh, the project grades from steepland with low rainfall along the SW side to comparable steeplands under higher rainfall in the NE; the general topography of the Changar area in which it is located is a complex mosaic of relatively flat uplands, river-margin areas and torrent-beds, among large areas of unstable highly-dissected steeplands. In the project around Cuenca in Ecuador the landscapes range from the high cold "páramo" around the rim of the catchment, through the mid-catchment of steeplands under medium rainfall to wetter very steep gorges in the lower catchment.

It is apparent that "averaging" assessments of land quality across any one of these project areas would not be particularly meaningful with regard to either deciding what ought to be done or how to implement any recommendations in terms of making blanket recommendations for improvement.

None of the three (in common with the great majority of comparable projects elsewhere) have either built-in capacities for formal monitoring of land quality indicators or arrangements with government departments to undertake such work for them.

The three projects were not visited with the specific intention of providing information for this Workshop: the Terms of Reference were different for each, and only in the last was the author specifically concerned with aspects of monitoring and evaluation. The experiences, however have a number of features in common which provide bases for the main comments in this paper:

; the possibilities of achieving improvements more through changes in technical and socio-economic approaches than by ever-more detailed refinement of technical specifications;

; possibilities for achieving conservation of water and soil as consequences of better husbandry of land and of improvements in its quality;

; the significance of soil moisture and the condition of the soil surface as mediating the partition of rainwater between infiltration and runoff;

; the importance of the development of credibility on the part of would-be advisers before effective partnerships and participation with farmers can be achieved;

; farmers' interest in achieving quick economic benefits from any measures being advocated;

; the relevance of farm families' perceptions of land-quality changes.

The experiences bring into focus some important basic factors which are of wider value than to these three projects alone.

BACKGROUND CONSIDERATIONS

There is much concern that land qualities in many parts of the world are changing, often for the worse, but there is not much formal monitoring, at specific places on the ground, of what is changing, in what direction and at what rates, even though this deficiency was noted years ago (e.g., FAO, 1977), and more recently by Hudson (FAO, 1991). Assessments of improvements in land quality attributable to field programmes and projects are commonly provided more by guesswork and wishful thinking than by the evaluation of the results of planned monitoring of chosen indicators.

People and land quality

Under undisturbed conditions, without human influence, "land quality" has no meaning. It gains its meaning when considering the uses to which land is or might be put by people.

Therefore changes in land quality are instigated by how people manage their lands, with consequent detrimental or beneficial results.

For the uses being considered in a given area, maintaining the land's quality in general terms relates to upholding or improving:

; its usefulness for the chosen purposes;
; its productivity;
; its stability in the face of climatic and other changes and disturbances (Downes, 1982, quoted in Shaxson *et al.*, 1989:23).

In rural areas, land quality is closely bound up with the nature and condition of vegetation, both native and planted. The quality of the vegetation depends on the chemical, physical, biologic and hydrologic characteristics of the soil as a rooting environment. These have to be considered at the millimetric scale with respect to, for example, porosity, water-holding capacity, structural condition, organic-matter content and activity etc. Thus monitoring of macro-scale indicators alone may not be able to provide all the significant information about condition and changes in land quality. What rural people decide to do in their fields in many cases affects directly these millimetric aspects: conversely if it is necessary to change millimetric aspects of the land so as to improve its quality, the people who work the land are those who will effect the needed improvements, and are therefore key players.

For the future, our concern must be with the rate of positive change in land quality, its stability, productivity and usefulness. Such changes can only come about if those who work the land are provided with adequate and appropriate types and means of support to their efforts at improvement.

Farmers, through long acquaintance, have often become accustomed to gradual average decline in land quality, about which they may believe they are unable to do anything. However, when improvement occurs as result of their own efforts - in terms of, for example, yields higher than expected under particular conditions, crops remaining relatively unaffected by drought for periods longer than expected etc. - farm families may be quick to note the changes and be more keenly aware of rapid improvements than they are of continual customary decline.

SUSTAINABILITY

The "sustainability" of land uses depends to some extent on economic and other factors in the human sphere, but in rural conditions it depends even more on the self-sustainability of the living components of land (Haigh, 1994:3). This refers particularly to (a) perennial vegetation, and (b) soil organisms, especially regarding their capacities as transformers of organic materials into humic derivatives, themselves having multiple effects on and in the soil (e.g., FAO, 1995:11, 24).

LEVELS OF DETAIL

Indices

When high-level decision-makers need information on whether or not negative changes in land qualities are occurring at national scale, single generalized indices - crystallized from aggregations of results from monitoring of a greater number of subject-specific indicators - may suffice at the abstract level. However, while such an index may provoke the response "something must be done", such indices are incapable of providing the technical detail required to determine what must be done - as in, for example, government policy decisions - which will beneficially alter farmers' decision making at field level.

Indicators

The GLASOD study (Oldeman *et al.*, 1991:12,13,18) identifies 12 types of soil degradation under four main headings:

; water erosion: loss of topsoil + terrain deformation/mass movement;
; wind erosion: loss of topsoil + terrain deformation + overblowing;
; chemical deterioration: loss of nutrients and/or organic matter + salinization + acidification + pollution;
; compaction, sealing and crusting + waterlogging + subsidence of organic soils;

and five causative factors, identified as:

; deforestation and removal of natural vegetation;
; overgrazing;
; agricultural activities;
; over-exploitation of vegetation for domestic use;
; (bio)industrial activities.

Outside a project or programme situation, monitoring of indicators of changes in land quality lead more often to "scare-stories" about land decline than they do to effective actions of improvement. The reason is that the interpretation and feedback do not normally result in rapid decision making which effectively alters the context within which the decline is occurring - except where farmers are using their own indicators.

Within project or programme situations, most indicators are formally linked to project objectives, at the end of a chain from Principal Objective → Intermediate Objective → Specific Objective → Activity → Expected benefit → Indicator. They may or may not be adequate to show changes in land quality if project objectives do not contain this criterion specifically. An example is provided at Appendix 1. Clearly, if this exercise is repeated for each Activity + Benefit under each Specific Objective, there would be a vast number of indicators. The number and nature of indicators eventually chosen will depend on the degree of detail one wants to know, and on the resources made available to do the job in timely fashion.

Even the relatively more detailed information from monitoring indicators at national level (which may have been used to construct the more abstract index, as above) themselves may be of little help in indicating the details of necessary remedial actions. For example, the following provide interesting information:

; vegetation changes detected by remote sensing;
; adverse changes in river discharges and their sediment loads;
; rates of changes in soil depth;
; rates of out-migration of people from an area;
; estimates of annual erosional loss of plant nutrients at national scale; etc.

But in-field action cannot be derived from them because while they show what is happening, they do not indicate in sufficient detail what has to be achieved, and how it can be done, to produce the desired improvements. On the one hand there may be insufficient technical detail, while on the other hand there is no indication of how rural people will react to a given proposed course of action.

Each suggests domains for deeper investigative action as to why the changes are occurring and what must alter before downward trend in land quality can alter to an upward trend of improvement.

Land is a complex of interacting factors (geology, topography, soils, hydrology, vegetation, other organisms, under the effects of climate, gravity and human actions) and always changing. There is a huge number of aspects for which change-indicators could be selected. The amount of detail which needs to be monitored increases as one moves along the sequence of questions:

1. Is any change occurring, and in what direction - positive or negative?
2. What is changing?
3. How great is the change?
4. How rapidly is it occurring?
5. What processes of change are in motion?
6. Why have these processes of change been set in motion?

It is at level (6) that we begin to see at what points, and of what nature, agro-ecologic and/or socio-economic interventions would be needed to turn decline into upward improvement.

It is insufficient however, on the basis of results from monitoring of indicators, to offer to decision-makers at any level such generalities as:

; "restore damaged soils to former levels of productivity";
; "improve pasture management";
; "increase afforestation";
; "increase effectiveness of recuperative periods";
; "reduce erosion and runoff".

Remote sensing and other broad-area investigations provide understandings at macro-scale, and usually result in the culprits "causing" land degradation being identified as "deforestation", "overgrazing" and "overcultivation". In conditions of rising rural populations and increasing desperation to find and retain anywhere to farm, attempts to prevent people doing these three things have been notably unsuccessful. But by considering their implications at micro-scale, it is possible to link production practices to increased stability and quality of land through active anthropization with organic materials. Each of the three macro-scale actions have in common three micro-scale problems which may more easily be addressed (Table 1).

TABLE 1
Culprits at macro- and micro-level

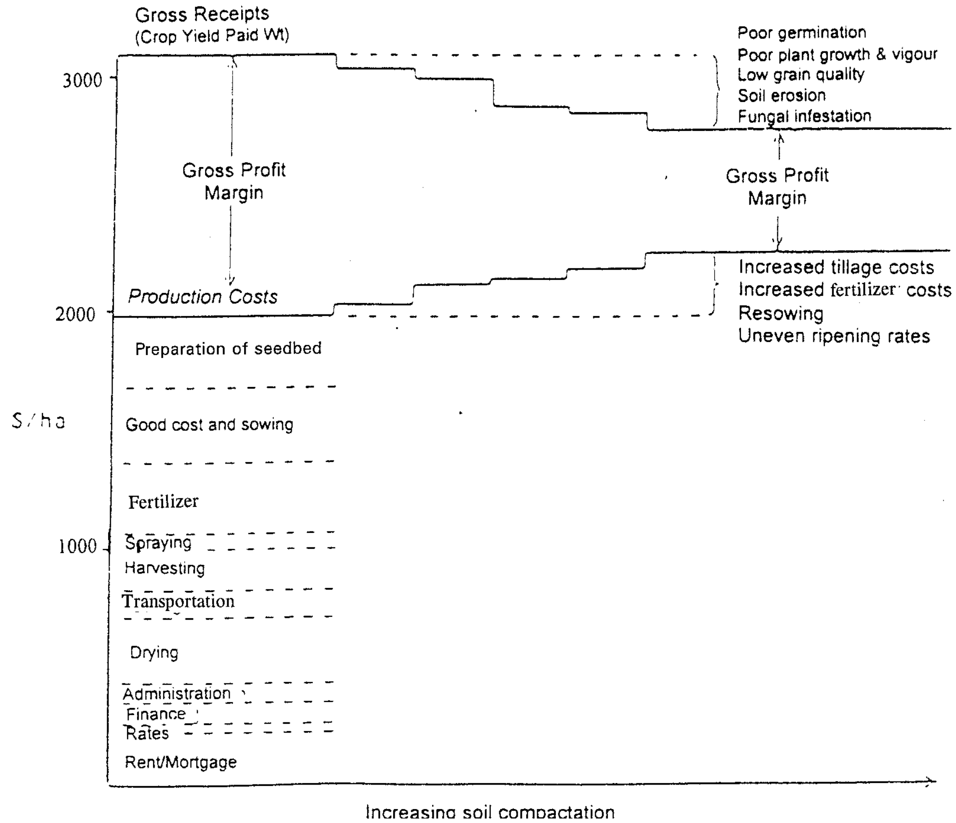
CULPRITS Macro → Micro ↓	Deforestation	Overgrazing	Overcultivation
Loss of cover over and on the soil	#	#	#
Loss of organic matter in soil	#	#	#
Loss of spaces in soil architecture	#	#	#

It is the micro-scale damages which result in, for example:

; poorer environment for root growth;
; more runoff and erosion;
; higher energy needs for tillage (e.g., Figure 1).

Conversely, improvements in these micro-scale features can result in decreased occurrences of "deforestation", "overgrazing" and "excessive cultivation".

FIGURE 1
Effects of soil compaction on gross margins under continuous cultivation (Shepherd, 1992)



Observations

Observing what is happening at field level gives clues to why problems of land degradation are occurring, and what sustainable improvements need to be instituted and maintained before land quality can be seen to have improved.

The most useful information will be that which combines the perceptions, observations and studies of the land-users themselves (derived from full-time experience of their own surroundings) with the complementary observations, understandings, studies and analyses by technical support staff.

The results of such observations must feed-back upwards so as to inform successive levels of decision-makers - starting with the farmers themselves, through technical administrators, to national policy-makers - about the necessary detailed content of suitable decisions about land use and management appropriate to each level.

CHOOSING SIGNIFICANT INDICATORS

It is difficult to know how and where to start the selection of a limited number of indicators from among the enormous range.

From a conceptual standpoint it appears that, for an overall first level of assessment of change in land quality, from which the outlines of remedial measures might be derived, three broad types of key indicators may be the most important:

a. Above the soil surface, as related with yields:

; **Cover close to the ground**: its density, distribution, duration, timing.
; **Stress in plants**: growth rates; timing and frequency of wilting; visible nutrient deficiencies or imbalances.

b. On the soil surface, as affecting particularly soil moisture and runoff+erosion:

; **Porosity of at least topsoil layers, in millimetric bands**: proportions of incident rainfall becoming infiltrated;

c. Below the soil surface:

; **Organic matter content and biological activity, as affecting multiple features**:

Soil architecture:
- structural stability;
- gas exchange
- water movement and retention/release;

Cation exchange capacity:
- nutrient capture and retention;
- pH buffering;
- nutrient availability;
- source of small amounts of recycled nutrients.

IMPORTANCE OF RURAL PEOPLE'S VIEWS

Monitored data, especially concerning both changes in conditions of natural resources and changes in people's activities, may have large margins of error ("background noise") related to uncontrollable variations in weather, politics, markets etc., and/or to long time-scales over which the changes occur. Qualitative information from a range of sources and indicators may then prove to be just as reliable and useful as quantified information in the assessment of the type, direction and rate of change of land quality in an area (Casley and Kumar, 1987).

Farm families use their own very pragmatic indicators of the condition of their crops and soils in making day-to-day decisions about how they will use and manage their lands. All policy changes which affect them are ultimately filtered through their decision-making processes, with results that may have positive or negative effects on land quality - or their decisions may block any change from occurring. If the land-users are ignored and marginalized in the process of deciding how to deal with problems of loss of land quality, the chances of them being interested in implementing suggested solutions is very slim, as past experience in several countries shows.

It makes sense to ask those who live on the land and have continuous knowledge of what is happening for information that can provide at least qualitative information, perhaps semi-quantitative data, and local history, from which the outlines of the more readily-perceived changes can be discerned. From these beginnings it can be decided what further detail and what complementary work may be needed to complete the information provided.

Farm families' comments may provide information on many different aspects of change which they perceive (using their own indicators, plus their views of the explanations of observed changes), for example:

- density of populations of people, and of animals, according to changes in land condition;
- patterns of out- and in-migration, and reasons;
- levels of satisfaction/dissatisfaction with present conditions of life in the farm/village community;
- changes in values of agricultural land;
- re-investment in agriculture, and/or in non-farm activities;
- effects of drought periods on crop growth and stability of yields;
- productivity of crops, pastures, trees;
- incidence and severity of pests and diseases of crops and animals;
- diversification of on-farm enterprises;
- reasons for doing farm operations in particular ways;
- uses and values of favoured indigenous vegetation;
- springflow and streamflow characteristics;
- colours of plants and soils;
- output:input relationships;
- soil physical conditions and energy needed for tillage;
- additional costs in re-planting areas from which soil and inputs have eroded;
- spread of salinized areas;
- increases and decreases in runoff and soil erosion;
- disappearances, re-appearances of birds and other wildlife;
- frequency of burning residues etc.;
- reasons for cutting/not cutting nearby forest trees;
- "traditional" practices for maintaining productivity, catching water, soil, etc.;
- reasons for/against implementing currently-promoted recommendations;
- innovations taken up after hands-on training;
- farmer-to-farmer transfers and adaptations;
- farming systems, equipment types, etc.;

; activity of worms, etc.;
; and others.

For examples see also: Bhuktan *et al.* 1994; Wijewardene and Waidyanatha, 1984; Hinchcliffe *et al.*, 1995; Tamang, 1993; Pretty, 1994; Cassel and Lal 1992.

If change in some form is not noted by farmers on the spot, it may not be very significant in the first instance, nor warrant much time spent on numerous and detailed analyses of a mass of factors. This is consistent with the pragmatic "subtractive-survey" approach that assumes that the situation is all right unless it can be shown to be otherwise (Shaxson, 1981). It is at this point that results from broad-area monitoring of key indicators (from remote sensing, market studies etc.) - which may show generalized views of land-quality decline - interlink with micro-scale results arising from farm-level monitoring.

At field-level it makes sense to start with characterizing the changes that farmers have begun to notice, then moving on to related linked changes of which farmers may not be aware, and only then, when available resources have been adequately deployed in this way, start more speculative monitoring of less-obvious changes that may or may not be important.

These comments and information may suggest to field staff particular pointers to further appropriate indicators.

Farm families will remark on things they perceive and see. Practical training to recognize small or hard-to-distinguish features can result in farmers becoming closely involved in monitoring. However, they may need assistance to foresee future problems or potentials which may be apparent to advisory staff but not yet within the perceptions of the farm families. These too may require monitoring, for which appropriate indicators would need to be identified by advisory staff: e.g., volatility of prices of particular crop; effects of too-deep tillage in bringing up more-unfavourable subsoil materials; too-great reliance on disc equipment for tillage, in view of potentials for severe sub-surface compaction developing; etc. (e.g., Vieira and Shaxson, 1995:9-11).

Farm-family members' statements on changes in output, food security, farming system etc. are comments about after-effects of combinations and integrations of changes in social, economic and/or technical details that may have taken place.

Within the area controlled by a community, the inhabitants' own comments are often important and illuminating concerning the nature and direction of change: such comments as:

> *"Things have/have not changed; they are different/better/worse (a) than before, or (b) than I would have expected under the present conditions [of e.g. weather pattern]".*

In deciding which indicators may be the best to use, the spirit of co-participation is favoured (and suspicions of outsiders' motives minimized) when the local inhabitants themselves are requested to suggest the indicators which they would use to characterize changes in the land that surrounds them, and in their own livelihoods. Such indicators are pragmatic, involve people's own self-interest, are likely to be enthusiastically monitored by those involved, and represent those things in the farmers' world which are changing most quickly and/or by the greatest amount.

Personal observations by technical staff may provide further insights - for example, sizes of boulders moved by the stream, presence of plants indicating incipient salinization etc. - and be complemented by records of indicators from hydrographs, meteorological records, laboratory analyses of soil conditions etc., as appropriate.

Examples of farm-level pointers to indicators

Farmers' comments make useful first "signposts" as to what may be most significant.

An example of a pointer to choosing appropriate indicators is provided by one remark of a small farmer in Costa Rica when asked his opinion about the effects of an (ongoing) project: *"El terreno se ve fofo" - "The soil is seen to be `fluffy'".*

This may be taken as an indication of changes in characteristics that can be quantified, such as: bulk density; porosity; pore-size distribution; mechanical resistance; root proliferation; etc (see, e.g., Cassel and Lal, 1992:71, 72). Similar comments are heard from farmers in other situations as well - including comments of disadvantageous soil changes, for example, as the result of long-continued application of mineral fertilizers (e.g., Tamang, 1993:7).

> *"In the village of Pacayas, we talked with Elias Zalaya, a farmer-extensionist about the improvements on his farm and in the village. The land had been abandoned as virtually worthless when he took it on some 10 years ago: `We planted maize here, but it just wouldn't grow'. The unimproved soils are barely a few cm thick, and beneath them is hard bedrock. The soil on his farm is now remarkable [from using green manures and leguminous high-bulk cover crops such as Mucuna]: where he has contour grass strips, the soil has formed terraces 1.3 metres high. The terraces are almost flat, and the soil thick, springy to the step, and covered with a thick layer of decomposing organic matter."* (Honduras: Pretty, 1994).

The description is an indicator of soil changes, but the nature of the changes (for purposes of comparison with other places, other times) would benefit by being characterized by quantification of, for example, organic matter composition, organic activity, texture, architectural (structural) condition, pH, nutrient composition and availability, etc.

Older inhabitants of an area may be able to provide qualitative - and perhaps semi-quantitative - information on changes in, for example, groundwater and streamflow conditions that have occurred over the last several decades.

An informant in the Changar project area in India told the author about the increase in land-eroding flood flows of a stream which formerly ran for much of the year tranquilly through his parents' land without causing damage to river banks. In more recent years floodflows have caused severe erosion of the stream banks and loss of significant areas of his cultivable land. Also in recent years the dry-season flow has been significantly less than it had been in his parents' time. He was able to indicate on the valley-sides the levels to which the worst flood each year generally rose, both presently and about 50 years ago. These are semi-quantitative indicators of changes in hydrologic condition of the catchment.

It was these comments, noted while standing on the river bank with this farmer, that initiated the understanding that one of the major problems of the region is in fact decline in porosity of the soil surface in forest and grazing areas, rather than human-induced erosion of soil as so commonly assumed. The understanding that lesser proportions of rainfall are entering the soil than in earlier years would help to explain increase in flood severity, falling availability of grass for fodder and of leaves and branches of trees and bushes for fodder and fuel.

This insight suggests that useful indicators of change, whether as continuation of downward trend, or as reversal to upward trend of improvement, would be the depth/time profiles of soil moisture changes and seasonal volume/time profiles of water availability in wells and streams.

> *"Farmers used indigenous indicators for determining the reduction in soil erosion [following their implementation of improved soil husbandry methods, again using high-bulk legumes and recycling of organic matter]. Some of such indicators included: soil becoming softer over years; plants growing uniformly; changing colour of soils from dull brown to darker colours; contour wall becoming smoother without slumpage during the rainy season; land strips in the contour farm becoming flatter; water flowing out of the field and water in nearby creeks are fairly clear in contrast to muddy conditions in the past; stone pebbles on the soils not visible any more; decreased frequency of landslides and contour wall slumpages; sticky soils becoming loam thereby absorbing much of rainwater thereby reducing the speed of rainwater flow on the surface; the increase in the depth of top soils on the farm; lesser and lesser deposits in the contour canals, soil traps and check dams and the like."* (Albay Province of the Philippines: Bhuktan *et al.*,1994).

These indicators are clearly useful and valid, and their monitoring is a matter of observation. Quantitative measurements of each of these would be difficult, expensive and time-consuming, and the measurement of only a few of the above qualitative indicators would be justified. But the difficulties of quantification of even a few in no way diminish the importance of the qualitative observations of the many which are here apparent.

In the state of Paraná, Brazil, the cultivation of farmland within about 100 metres of a particular stream earlier had been abandoned because of the increased incidence of a small black biting fly known locally as "Borrachudo". Detective work by local field staff showed that excessive applications of pesticides had resulted in significant amounts washing into the stream and killing the fish which otherwise ate many of the aquatic larvae of the fly. Without this control, the fly multiplied to unacceptable numbers and the land was abandoned. Advice and training on more restrained use of pesticides by the farmers resulted in much less pesticide reaching the stream; the fish eventually returned, again exercised control on numbers of the fly, and the stream-side areas were again brought back into tillage (author's notes from a field trip, 1986).

Farmers' observations and responses led to detailed investigations and characterization and monitoring of indicators of detrimental changes in qualities of both land and water. Observation of indicators led to investigations that led to actions, and subsequently also followed the beneficial changes that followed application of the chosen remedies.

OTHER SOURCES OF INDICATORS

Non-farm people

Other sources of relevant pointers to indicators are staff in both the technical and administrative arms of the district administration: advisory staff can provide information on commonly-observed changes across the District as a whole which individual farmers may not have remarked; the District Roads Engineer may comment on the increased/diminished costs of road maintenance due to changes in severity of runoff and erosion; the popularity of local political figures may be affected by their support for (or indifference towards) rural improvement programmes which have resulted in improved land quality; variations in the local water authority's costs of treating water for urban/domestic use may indicate changes in the sediment and chemical loads in river-flow from the catchments upstream.

Photography

It is important also to add one's own observations and interpretations to what farmers say and show. In addition to note-taking, an ordinary hand-held camera is an important tool for recording observations which otherwise may be difficult to quantify or to describe adequately in words. Although it has great potential for recording serial changes at particular places, the simple camera is much under-used for this purpose. Photography merits more promotion as part of the monitoring record. In addition to single photos in two dimensions, two photos of the same scene, from viewpoints only a few centimetres apart, are in most cases sufficient to record three-dimensional views which can be recreated even with small and inexpensive viewers, including pocket stereoscopes.

Photographs can provide visual records of changes and differences over time, and from place to place, of physical features which otherwise would have no permanent record (see for instance Tiffen *et al.*, 1994). Semi-quantitative comparisons may be possible from a carefully-planned series of photos of the same place at different times, and of a common feature in different places at almost the same time. Photo sequences of time past may suggest what complementary indicators should or could be measured in future.

Scoring

Where quantitative data may be difficult to define and collect, systems of scoring of particular features provide an intermediate and valid step. An example relating to land condition/quality is summarized in Appendix 2 (Douglas, 1995: 17-26).

FEEDBACK TO FARMERS

To become partners with farmers in improving land condition and quality, it is essential to provide them with feed-back, and to discuss with them the results of analyses which have been undertaken both on data which they themselves have collected, and of other monitored information. This is a powerful way of initiating discussion on making further improvements to land-use practices and to the indicators that would be monitored to follow change and progress.

FARMER-TO-FARMER SPREAD

Farmers experiment with and maybe adapt new ideas to their individual circumstances before they decide whether or not to adopt them. An indicator of their enthusiasm for and satisfaction with some new method, which may include better land husbandry practices, is therefore the rate of spread through informal farmer-to-farmer contacts independent of any efforts by extension staff (see, for example, Bunch and Lopez, 1994; Cheatle and Njoroge, 1993).

SUSTAINABILITY

In rural situations, farm-family members' attitudes, perceptions, observations, suggestions, knowledge, insights, interpretations and comments can be particularly important. It is their views of apparent benefits or costs arising from changes which will determine whether they will sustain the improvements in future. These comments may also indicate whether they are becoming more, or less, satisfied with their situation because of changes in the condition and quality of the land. Such comments may indicate a (human) aspect of sustainability affecting their expected permanence of residence. If they are increasingly dissatisfied as time goes on, many will leave an area and fail to maintain its productivity. If, as the land quality improves, they are increasingly satisfied, the land will be well husbanded and maintained. Their degree of satisfaction is also a useful indicator of change in land quality, though once again the reasons for change and the nature of necessary improvements require more detailed analysis than mere monitoring of the indicator.

CONCLUSION

Selected indices and indicators alone can do no more than show that a situation is changing: the more specific the indicator, the closer the understanding of what detailed features of land are changing. But if remedies or improvements are to be applied, monitoring of indicators must be accompanied by feedback plus adequately-informed decision-making which ultimately produces a better impact of rural people on land quality through the filter of their own self-interested decision making.

Decline in land qualities highlighted by macro-scale indicators - such as deforestation, runoff and soil erosion - aggregated across a region or country, often have their bases at micro/millimetric scale, such as soil architectural/structural conditions and an individual farmer's decision-making processes. Understanding at this detailed level may be essential before appropriate strategies can be devised and policies made about how to effectively address and reverse the decline. However, when improvement has begun, increasingly aggregated and abstract indicators may be all that are necessary to show that improvements remain on course.

Rural people directly modify the land and affect its qualities, stability, productivity and usefulness. Thus, their views, observations, perceptions, indicators, records, requirements and aspirations are essential components in characterizing the present condition of the land, the history of changes to date, and how they would like to see it in future. It is through their field-level decision making and its consequences that improvements may be initiated and maintained. Under growing pressures of population, and of rising demand for agricultural and other rural products, traditional ways of maintaining the land's quality and productivity are often no longer adequate. It behoves the technical, administrative and political communities to become partners in helping them to develop their own skills, and the potentials of living organisms - particularly as they affect the self-recuperating capacities of soils and perennial vegetation - to improve the land in ways that can be sustained.

The problems of land quality decline may be recorded in purely technical terms. But their solutions cannot be provided by technical bio-physical "fixes" alone, nor (alternatively) by socio-economic "fixes" alone. Interdisciplinary work in partnership with farmers to ameliorate and solve the problems must acknowledge the necessity for working in an "ecology of disciplines", none of which can afford to work alone (Poole, 1971). In such a context, "indicators" do no more than indicate. Solving the problems to which they point requires additional work by field staff and others, in partnership with farm families, to identify and successfully implement sustainable improvements.

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APPENDIX 1

FROM PROJECT OBJECTIVES TO POSSIBLE INDICATORS - AN EXAMPLE

A. LINKAGES

Principal Objective

The adequate management and conservation of renewable natural resources, for the purpose of diminishing the rate of erosion, and at the same time working towards augmenting productivity in the agricultural, pastoral and forestry sector, thus obtaining indirectly improvement of the quality of life of the communities located in the four sub-catchments; this would provide protection to the investments made by [the Corporation] in the hydro-electric complex and extend the useful life of the dam ...

Intermediate objective 1	**Intermediate Objective 2**	**Intermediate Objective 3**	**....**
Specific Objective 1.1	***Specific Objective 2.1***	etc.	
Activity 1.1.1	***Specific Objective 2.2***		
Components			
Benefit 1.1.1.1 ->Indicators Benefit 1.1.1.2 ->Indicators	as ←		
Activity 1.1.2			
Components			
Benefit 1.1.2.1 ->Indicators			
Specific Objective 1.2			
Activities Benefits as above Components Indicators			
Activity 1.1.2			
Benefit 1.1.2.1			
etc. ↓			

(continued →)

B. EXAMPLE

Intermediate objective 1

Creation of an extension service to promote participation of communities and individuals in managing and conserving renewable natural resources ... among some 10 000 small farmers occupying some 22 000 ha. Also to install and manage 7 sets of runoff plots for obtaining data about rates of erosion.

Specific Objective 1.1

Crop, pasture and forest production, and conservation of soils in 31 mini- catchments of 3 sub-catchments by the end of 1996 ...

Activity 1.1.1

180 demonstration plots

Components:

.1 Physical works
.2 Vegetative strips
.3 Fruit trees
.4 Forest trees
.5 Inputs and seeds
.6 Fencing

Benefits expected, for example from

.1 Physical works

EXPECTED BENEFIT		POSSIBLE INDICATOR	
	Short term		
a.	Catch runoff water	a.	Water lost: none/some/all
b.	Catch eroded soil, organic matter	b.	Soil held: much/little/none
c.	Limit rilling and initiation of gullies	c.	Rills etc. below: yes/no/frequency
d.	Promotion of cultivation along contour	d.	On contour: yes/no
e.	Maintenance of yield levels	e.	Year:year records: farmers' assessments
f.	Increased soil moisture	f.	Sampling
	Medium term		
g.	Less sediment available for movement downstream	g.	In streamflow: more/less
	Soil nutrients less quickly exhausted		
h.	Better results from application of inputs	h.	Results of soil sampling
i.	More cash income	i.	Yields; farmers' records, comments
j.		j.	Farmers' records; visual evidence
	Long term		
	Less sediment entering reservoir		
k.	More secure food supplies per family	k.	Less rapid loss of capacity
l.		l.	Farm-families' comments; survey results
	Possible dis-benefits		
	Part of field taken out of production		
m.	If banks break, damage worse than before	m.	Measure widths, calculate %
n.	Costs of construction and maintenance	n.	Visual evidence
o.	Inconvenience to farm operations	o.	Farmers' records, memories
p.	Time and labour for construction	p.	Farmers' comments
q.	Yield benefits delayed	q.	Farmers' records, comments
r.		r.	Research whether soil or water effect.
WHAT ARE FARMERS' OPINIONS?		FARMERS' OWN COMMENTS MAY PROVIDE MOST APPROPRIATE INDICATORS.	

Similarly for other Objectives, Activities, Components, Benefits.

APPENDIX 2

SCORING - AN EXAMPLE

Land Quality Indicators Shifting Viewpoints

- Indices and indicators not enough: macro-scale decisions must have taken account of micro-scale factors, e.g., a farmer's decision-making processes, soil architectural conditions, etc.
- Accelerated runoff and erosion are consequences, not prime causes, of prior land/soil problems: consider deforestation, overgrazing, excessive cultivation from different standpoint.
- Significance of soil as the environment (biological + physical + chemical + hydrologic) for rooting, and as buffer for rainwater.
- Critical roles of soil-biologic dynamics, and thus of life-based self-recuperating capacities of soils and perennial vegetation.
- Farm-families' observations, perceptions and comments are full-time, integrative, a nd are prime entry-points for choosing indicators.
- Importance of qualitative information, and of photos.
- Improvements in sustainability are chiefly possible only via integration of agro-ecologic and socio-economic considerations by the multitude of farm families.
- Key indicators:
  - cover close to the ground;
  - signs of plant stress;
  - soil porosity;
  - organic matter and processes;
  - streamflow characteristics;
  - farm-families' information.

Source: Qualitative guidelines for monitoring and evaluation of better land husbandry. (Douglas,1995)

Land quality and other indicators of sustainable development statistical data, quality control and problems of aggregation

AN OVERVIEW OF THE WORK IN THE STATISTICS DIVISION

Recently, work has started to develop land quality indicators (LQIs) to monitor changes which make an impact on sustainability of land resources in meeting human needs. This work takes into account current status of land resources along with a measure of extent of its utilization for meeting today's need and impact on future requirements. These indicators help in monitoring the major land issues and answer policy-related questions. In the work on LQIs land issues have been grouped into three clusters viz. inappropriate land-use systems, land degradation and inadequacies in the policy environment for land users. Looking from a limited angle of agriculture (crop and animal husbandry) some of the indicators on LQIs deal with items such as trends in crop yields, crop nutrient uptake/fertilizer use, farm gate/market prices for inputs, visible soil erosion (area, degree and proportion of land affected), major land-use, proportion of farmed area with recognized title, ratio land/people and livestock/people, intensity index (permanent cropped area/total cultivable area), diversity index (number of species x area of land-use type)/total area. This work on indicator definition also serves the broader context of sustainable development.

The Statistics Division (ESS) is responsible for collecting, analysing and disseminating statistics on food and agriculture, including data on agricultural inputs which are relevant to the environmental area. ESS has so far not made any effort to compile or collect LQIs but this paper briefly lists the current status of statistical data (called LQIs data hereafter) for compiling them, indicating its reliability and efforts being made to improve its coverage in future.

The agricultural database maintained by ESS contains time-series data (starting 1961) for over 210 countries and 1500 items on the production and trade of crops and live products, agricultural machinery, fertilizer, pesticides and insecticides (trade only), land use and population. These data series contain national aggregates/averages and are maintained in the form of supply/utilization accounts (SUAs) for most commodities. A SUA consists of elements that are basic or essential such as production, imports, exports and domestic use, and those that are supporting or supplementary such as animals slaughtered, harvested area or seeding rate. The basic equation of a SUA equates supply with utilization (demand) for a given period.

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It has long been recognized that it is no longer meaningful to deal separately with individual statistical series, such as those for production and trade, etc. The statistical framework of SUAs has been developed with the aim of providing reliable data series for various uses. To derive these data series ESS performs three main activities, namely, **collection** of country data through questionnaires sent to member countries and from publications and reports, **selection** of the data collected after careful analysis and scrutiny and **filling-in gaps** when necessary. These data series are published in yearbooks and other *ad hoc* publications and also disseminated through FAO's computerized databank World Agricultural Information Centre (WAICENT).

WAICENT is a corporate database composed of two linked data systems: FAOSTAT, which contains statistical information, and FAOINFO, which contains textual information. FAOSTAT contain a constantly updated collection of time-series data on demography, agriculture, fisheries and forestry from 210 countries and territories, as well as data on trade flows, food aid, development assistance and the results of the World Agricultural Census and household budget and food consumption surveys. The Centre has been created to provide clients - including governments, research institutions, universities and private users - with fast, economical access to FAO's vast library of information on agriculture, fisheries, forestry, nutrition and rural development. As it becomes fully operational, WAICENT will allow users to retrieve information - initially in English, French and Spanish - from a wide variety of media, including floppy disks, CD-ROM and mainframe tapes as well as via "on-line" access through computer networks and telephone lines. FAO is promoting wide access to WAICENT through its new "Computerized Information Series" which collects WAICENT products on floppy disks or CD-ROM. The series includes a PC dissemination module of WAICENT which contains statistics collected since 1961 on population, land use, production, trade, food balances, forest products and food aid. Fisheries data will soon be added. The series also includes a digitized Soil Map of the World in seven volumes and 63 diskettes, the results of decades of study on the soil situation of each country.

LAND DATA

The importance of land data lies in its use as an inventory variable and an object for monitoring. A complete land-use database should also serve as an alert for emerging land-use resource problems. It should include detailed information on land uses/cover along with losses and gains between sectors, e.g., between forestry and agriculture, between agriculture and manufacturing, etc. This aspect of intersectoral relationships and connections has not been handled adequately in policy studies and efforts are needed to address them. The value of land-use data is influenced by its timeliness, coverage, accuracy and structure. The data must fit policy needs and be at appropriate disaggregated levels to make them useful. This recognizes the need for suitably geo-referenced data at the national and sub-national levels for developmental work.

National data on land use available in the ESS data bank include the following categories covering:

; total area (i.e., area including area under inland water bodies);

; land area (i.e., area excluding area under inland water bodies);

; arable land;

; land under permanent crops;

; permanent meadows and pastures;

; forest and woodland;

; other land (includes built-on areas, roads, barren land, etc.).

These data are published regularly for continents and countries in the FAO Production Yearbook for selected years. Similar data at sub-national level are available for a few countries for selected years and are generally related to data collected in agricultural censuses. ESS also has data on irrigated land, including land irrigated by controlled flooding. FAO compiles these data from questionnaires forwarded to countries and national statistical publications and an array of other sources such as project reports, including studies available from other FAO Divisions and economic journals. This database is not always up-to-date for several reasons. In many countries there is no established statistical system to generate such data. In some cases the primary sources go back more than twenty years. It is also clear that no single source can provide all of the data required to study land-use patterns which introduces the additional problem of consistency.

The quality of international data depends first on the quality of data collected by national institutions and secondly on success in compiling data collected from different sources into one framework for international use. The only source of data at international level is the data collected by the countries themselves. The Agricultural Census or an agricultural survey is often the basic source for such data collected by the countries. These data relate to arable and permanent crop land while other classes such as marginal land and eroded land which are of great environmental importance are obviously ignored (or greatly underestimated). Obviously, data on forest and water bodies are often missed. Even in those countries where a system for collection of agricultural statistics exist, there is still a need to improve the system and the reliability of the data.

Unlike land cover data, almost all land-use data are collected on a sample basis. These sample surveys are designed to provide estimates of known accuracy and reliability for the area sampled. It is desirable to have a full cadastral survey but very few countries are in a position to find resources to prepare one. In such situations, one is left with the Agricultural Census (which is a periodical operation in many countries) and surveys. These censuses/surveys cover agricultural holdings rather than the complete land area.

PROBLEMS IN COLLECTION OF DATA

Assembling and tabulating this enormous mass of data in internationally comparable form presents many problems arising from differences found in countries' data as regards to concepts, definitions, coverage and classifications. From the early sixties to the present day, particular attention has been given to these problems at various international and regional meetings, seminars and training workshops/national demonstration centres such as those promoted by ESS in collaboration with UN Economic Commissions, the Inter American Statistical Institute, the Conference of European Statisticians, the FAO Statistics Advisory

Committee of Experts[1]. Some of the common problem which are faced in collection, compilation and presentation of data on land use are given below:

; ***Non-reporting:*** In a given year, generally about two-thirds of the countries provide some data on land use.

; ***Incomplete coverage:*** Data on fallow areas, pasture, forest and shifting cultivation are very rarely available. Shifting cultivation presents considerable environmental problems (and many nations today face environmental damage after centuries of this activity) yet this is one category where data are not available for various reasons.

; ***Concepts and definitions:*** There is no universally-accepted standard or definition for some of the classifications. Two important issues in this connection are as follows:

a. Definitions of the categories of land used by various countries are sometimes different from those given by FAO for certain items. The best example of this is that most countries take arable land as the land which is potentially cultivable, whereas the FAO definition refers to land under temporary type crops, meadow and pasture. This problem is so widespread that it may be necessary to modify the FAO terminology. This is more so because one cannot arrive at an estimate of arable land by some easy method such as adding areas sown or harvested because of multiple sowing and harvesting and inter-cropping with areas double counted.

b. Definitions used by reporting countries vary considerably and items classified under the same category often relate to differing kinds of land. For example, once we arrive at a definition of pasture and forest land we are confronted with the concept of wooded land. Wooded land is applied by some countries to refer to what statisticians prefer to call wood land. In most developed countries animals graze in these areas. Statistically, the areas where animals graze are classified as pasture, while those involved in resource assessment classify them (on the basis of satellite imagery) as wooded land. Similarly there are also problems about classification of area under some plantation crops, e.g., if rubber plantations should be classified as wooded land or woodland or forest.

; ***Problem of aggregation:*** In view of non-reporting and under-coverage it becomes difficult to get world and regional totals. However some efforts are made to prepare such aggregates using approximations and projections. This exercise seriously affects the reliability of the data between various continents.

; ***Outputs of the data:*** Up until recently FAO data have been published in Production Yearbooks and other reports. However, the audience we are addressing today has wider interest in environmental matters. There is also an interest in receiving data electronically and in formats that can run easily on much more sophisticated software. Today users are keen to calculate indices, ratios and indicators and switch between graphical packages and picture images which can be transmitted and down-loaded from site to site.

[1] For illustration, mention may be made of the Conference of European Statisticians (Geneva, 1995) where detailed discussions were held on Handbook of Concepts and Definitions used in International Collection of Food and Agriculture Statistics, and the "National Demonstration Centre" on supply/utilization accounts (SAUs) organized by FAO (Harare, one week in November 1995) to train national statisticians.

However to accomplish this task it is necessary to make the data more objective and complete.

ENVIRONMENTAL AND SUSTAINABILITY INDICATORS: NEW DATA NEEDS

ESS is also charged with the responsibilities on aspects of environmental statistics, particularly in the context of sustainable development. The Division has in recent years participated in the development of appropriate indicators and identification of relevant variables. Although the existing data available in ESS can be used to construct the indicators, in a recent exercise in the Division it has been identified that there are two important classes of variables, viz., those which are directly related to risk and those which are related to potential risk. Most of the ESS data available today are indicative of potential risk, i.e., they indicate the potential for environmental damage but not whether and where it actually occurs.

ESS is planning to bring out a manual on "Agricultural-environmental statistics and indicators for sustainable development, a guide for national statistical offices in the area of agriculture and the environment". ESS has a major role here for development efforts in preparing guidelines for collection, compilation and interpretation of data as well as in imparting training to national staff. It has also been clearly identified that there are areas of new data needs which call for additional efforts. Considerable efforts have been made to expand the coverage of countries on input statistics and attempts are being made to get full coverage of data on pesticide use and use of other inputs. New areas of interest include items such as: productivity, surface water and groundwater quality, land use and soil quality/soil management, use of agri-chemicals, agricultural biodiversity (genetic and species diversity, wildlife and natural habitats and diversity), pollution and waste management, climate change, water use (irrigation) and quality, agricultural extension costs, management of fertilizer and pesticide.

The UN Department for Policy Coordination and Sustainable Development project on development of methodologies for calculating sustainability indicators as a follow-up to Agenda 21 (chapter 40) has led to the preparation of methodology sheets for indicators dealing with use of agricultural pesticides, use of fertilizers, arable land per caput, irrigated land as percent of arable land, cost of extension services provided and investment in agricultural research.

Potential sources for this kind of information are the Agricultural Census and *ad hoc* /regular surveys. The Division has considered this aspect while issuing guidelines to countries for conducting the census. It has also been recognized that detailed information required by policy-makers cannot be obtained through census programmes and it is necessary to restructure other sources for collection of data (Narain, 1995).

LQI: SOME OPERATIONAL ASPECTS OF DATA NEEDS

Before going to the efforts made by ESS for improving the future scenario and having listed the various aspects of LQIs data, it is necessary to mention some of the operational aspects of collection of data required for compilation of LQI. Collection and compilation of data pass through three stages. The most important in the series is the last in the sequence of creation of the data bank, i.e., the end use of the data. While making any recommendations for data collection to member countries it must kept in mind who are the data users, what are the data needs and how these data would be used.

The second stage in the sequence is the formulation of concepts and definitions of the attribute required to be measured. This question indirectly centres around the size of data collection operation, human resources and equipment required for collection of the data. The matter could be understood more clearly by looking at some of the new items recommended for inclusion in the World Census of Agriculture Programme 2000 presented in the next section. ESS has faced considerable problems while including some of the essential items on land and soil in the programme. The issue under consideration was whether the investigators who are going to collect data would be able to measure the attribute.

The third stage is the presentation of the information/data. Here, apart from the format and media of presenting data, it is also important to take into account who is the decision maker concerned with making policies for taking corrective measures. Thus it has been thought appropriate by ESS to limit its efforts to the field of agriculture in discussing the indicators. Needs of forestry and fisheries may be taken up separately to draw the direct attention of the concerned departments.

RECENT EFFORTS

ESS, having analysed the need for more reliable data to meet the more recent demands on land use and land cover and other areas connected with natural resources and environment, has taken action in two directions: first, to improve upon the methods for collecting new data, and second, using the existing data provided by remote sensing techniques, to improve the available data on land cover wherever it is feasible. In the case of the former, mention may be made of issuing guidance for collection of data under the World Census of Agriculture 2000 and development of the area frame technique for undertaking sample surveys. These efforts are briefly discussed below.

a. World Census of Agriculture 2000

The World Census of Agriculture 2000 Programme, like previous census programmes, assists countries by providing definitions, concepts, standards and guidelines for censuses in the decade 1996-2005 in order to generate a database of internationally comparable figures. This Census, like the earlier one in the series, collects a large amount of information to get a few key indicators to measure the change in the status of agricultural activity. These indicators include area under cultivation and other global land use, area under compact forest type tree cover, human-land and livestock-land ratio, pasture and grazing land, etc. A change in these indicators can point to whether current agricultural practices are sustainable.

Technology development requires more and better information on agro-ecological and socio-economic factors and on use of land and natural resources. Keeping this in view and "land theory of value", which puts physical characteristics for use of land at the centre of economic analysis, this programme for the first time recognizes the need for collecting data on environment related issues. The present census has included, in addition to the information on size of holdings and type of irrigation facilities available, the information on distribution of agricultural land by agro-climatic/agro- ecological zones[1]. It has been recommended that these data may be collected together with a minimum set of data on quality of land. This information would provide:

- a framework for determining which kinds of government policy and research would be needed for agriculture on different types of land;
- data for developing sustainability indicators at the global, national and sub-national levels;
- information for establishing targets and thresholds for safe and sustainable agricultural practices; and
- data for an information system to analyse environmental, social and economic data in an integrated manner.

The Census Programme are also recommends augmenting existing information on agricultural practices by including more information related to area irrigated, area affected by salty soil or high water table, area with irrigation potential. As regards shifting cultivation, in addition to the question "whether shifting cultivation practised" the programme suggests gathering information on "year current parcel cleared for cultivation". Similarly the programme has, for the first time, suggested that information on "amount of inorganic fertilizer applied per crop", "frequency of pesticide applications per crop" and "crops with high yielding/traditional varieties of seeds" also be collected for analytical uses.

However, the agricultural census is a worldwide operation and the framework, concepts and definitions are designed keeping in view the level of literacy/knowledge of the respondents in various countries. While this allows meaningful data to be collected for policy-makers, the preparation of frames for undertaking in-depth studies and making international comparisons, there are necessary compromises made that impose some limits on the usefulness of the data for comparison purposes.

Some of the other indicators in the suggested list, like productivity, use of agri-chemicals, water management and climatic changes can only be collected by sample surveys because agricultural activity is seasonal in nature (at least in most of the developing countries where this activity is being done in the traditional manner as a major means of livelihood). The agricultural census is a one time operation in a number of countries and may be conducted during an abnormal year[2], and derived statistics can be deceptive. Thus data from agricultural censuses could be used only for limited purposes.

b. Area Sample Surveys

One of the perennial problems in data collection in most developing countries is the non-

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1 Even in countries where no work has been done on documentation of agro-ecological zones, the census can collect the following information on soil quality parameters for each holding: soil type (sand, loam, light, clay, heavy clay); soil colour (black, grey, yellow); soil depth (< 30 cm, 30-90 cm, >90 cm); soil salinity (nil, moderate, high); surface drainage (good, moderate, poor); rate of percolation (high, moderate, low); soil degradation (light, moderate, strong, extreme); relative area (of the holding) of degradation (6%, 6-10%, 11-25%. 26-30% and >30%)

2 Since preparations for undertaking an agricultural census are to be done much in advance, generally it is not possible to ensure that the reference year should be a normal one.

availability of a suitable sampling frame. Construction of the frame in the traditional manner is a time consuming and costly affair. Often, by the time a frame is prepared it is outdated. This feature seriously affects the quality of data collected. To circumvent this problem the FAO Statistics Division has proposed to publish a technical manual on the subject. The first volume of the manual entitled "Multiple frame agricultural surveys - current surveys based on area and list sampling methods" is a contribution to the statistical design, organization and implementation of large-scale agricultural sample surveys based on current information. The manual intends to introduce the subject in a straightforward and practical manner, maintaining, at the same time, its statistical rigor. Procedures are presented from the viewpoint of the considerations and steps needed to initiate and ensure the maintenance of an agricultural statistical data collection programme where experience with area frame and multiple frame sampling methods is lacking.

The manual describes multipleframe sampling survey designs that combine an area sampling frame and complementary list frames of agricultural holdings. The list frames of agricultural holdings utilized are of two types:

; lists of holdings used for the estimation of agricultural items studied also through the area frame questionnaire. These are relatively short lists (easy to update and combine with the area frame) of special holdings that correspond, for a given item, to a significant percentage of the total estimate. For instance, a list of the agricultural holdings with the largest area for a certain crop or with the largest number of livestock heads;

; list frames of holdings used for the estimation of items for which area frame estimates are not obtained. For instance, lists of holdings to estimate horticultural production.

The above-mentioned multiple frame statistical model might be the most practical way for a country to produce annual agricultural statistics: estimates of planted and harvested areas, areas intended for harvest, potential and actual yields and production of crops; livestock estimates, grain stocks, social and economic characteristics of agricultural holdings and of farming systems. The use of an area frame is necessary to geo-reference micro data, which are necessary for the development of meaningful environmental statistics.

The agricultural survey designs described in the manual represent an improvement over the more usual methods based exclusively on a list frame of holdings. In fact, apart from other considerations, the area frame methods generate more precise estimates of agricultural areas, a important item studied in all agricultural surveys. Multiple frame models utilize cartographic materials (e.g., satellite images, maps and aerial photography) and area measurement instruments for the construction of the frame and for data collection.

It should be noted in particular that satellite imagery has become available to a large number of countries only during the last few years. The availability of images as a tool for area frame construction greatly facilitates the application of multiple frame survey procedures. Furthermore, the accumulated experience of adapting area sampling frame models in many countries, and in general the increasing availability of computers for data processing provide an opportunity for fostering the use of multiple frame models for national statistical agricultural programmes.

However, the decision to base an agricultural survey on multipleframe sampling methods should carefully consider, as is the case with any statistical model, the local conditions and requirements. In fact, to be appropriate for a country or a region of a country, the statistical survey design and the implementation procedures should satisfy a number of conditions. In the first place, the sample design and the construction of the frames require trained staff and availability of suitable cartographic materials and equipment. Secondly, the survey implementation requires that certain agricultural characteristics such as proximity of the holder to the holding must be met.

The manual describes the initial steps and considerations required for the planning of a large-scale agricultural survey and refers to the problem of choosing an appropriate sampling design. The major part of the manual describes the construction of an area sampling frame using physical boundaries for strata and sample units. It covers the preparation of the complementary list frames, the replicated area sample selection, the organization and the survey data collection procedures, the multipleframe estimation methods and the calculation of sampling errors. It includes area frame construction procedures using different combinations of cartographic materials (satellite images, maps and aerial photographs), measuring instruments and equipment. It also covers the case of area sampling frame methods that use geometric (square or rectangular) sample units without physical boundaries.

The second volume of the manual to be published shortly, will illustrate a large number of national case studies on agricultural surveys based on multiple frame sampling methods prepared for FAO by experts in the field.

c. Remote Sensing

With the rapid development of space technology there is great hope of using remote sensing techniques as a means of improving land-use statistics. In particular, the use of remote sensing for agricultural statistics seems to have the greatest potential in countries where the statistical system is not good enough to produce reliable and timely data to meet the increasing needs of users.

It is extremely useful to classify land cover into main categories of land-use like forest areas and urban areas. It is a first line weapon in the monitoring of the environment (including drought degradation and fire damage to land) and in dealing with desertification, deforestation and pollution.

Although remote sensing by itself can provide only the broadest land-use information it does constitute a valuable enhancement to ground-based systems except for building sampling frames. ESS recently undertook a study of the land-use data in relation to remote sensing efforts in three countries. In these cases a key was developed (which is not unique) to make adjustment in data available from different sources. It is hoped that this method could be used for many countries in the African region. The classes which matched most closely our data are shown in Table 1.

TABLE 1
Various land-use or cover terms found in a comparative study in three contrasting countries

Arable Land
- agriculture in sloping areas
- intensive agriculture in flat areas
- agriculture on sloping or steeplands
- receding rice fields (flood recession cropping)
- paddy rice fields
- swidden agriculture (shifting cultivation)
- field crops horticulture

Permanent Crops
- orchards
- olive trees
- deciduous fruit trees
- citrus or bananas
- vineyards

Permanent Pastures
- pastures and related grasslands
- swampy areas
- marshes
- grassland (flooded or not),
- abandoned grassland
- savannah
- abandoned shrub land
- degenerated forest or maquis

Forest and woodland
- evergreen forest
- plantation forest
- coniferous forest
- deciduous forest
- mixed forest
- secondary forest (flooded or not)
- flooded forest
- mangrove forest
- woodlands
- natural shrub land
- Mediterranean maquis
- broadleaf forest

Other land
- highly dissected and eroded land
- low shrub and bare rocks - garigue
- urban areas
- marginal lands
- barren land or rocks
- eroded land and beaches

The above list is a mix of categories coming from three different land cover legends worked out during the study.

The initial efforts have been a valuable experience and resulted in the recognition of an underestimation of arable land in one of the case studies. This exercise has shown that it is possible to use remote sensing and GIS techniques to build data for land-use classification even though the original data are land cover calibrations. The keys in each country study differed and what remains to be accomplished is the development of a standard key for widescale use especially for the Africa Land Cover Study (AFRICOVER).

OTHER RECENT EFFORTS UNDERTAKEN TO IMPROVE THE QUALITY OF DATA AND INFORMATION

In addition to the above-mentioned efforts in improving the reliability and coverage of the data, ESS has undertaken reviews to adjust the area under forest cover in relation to the results of the FAO Forest Resources Assessment Project whenever possible, thus recognizing that such assessments are complementary to national statistics. Furthermore, the Division has also taken on board some of the data from the Water Resources, Development and Management Service of FAO on irrigated areas as presented in their AQUASTAT files to make adjustments similar to those made with remote sensing information.

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Considerations and constraints on the use of indicators in sustainable agriculture and rural development

THE BASIS AND NEED FOR INDICATORS

Indicators are pointers. Used effectively, they can flag important conditions and trends that can help in development planning and decision making.

Sustainability indicators look at economic, social and environmental information in an integrated manner and are growing in importance with the advent and follow-up to Agenda 21. They are now challenging countries and the development community to:

a. develop better information collection and reporting systems especially for natural resources (environmental) indicators;
b. integrate environmental, social and economic indicators for greater sensitivity in planning and decision making toward sustainable development; and
c. report regularly and reliably on conditions and trends.

The institutional and professional capacities of countries and communities, especially the poorer ones, to adapt and apply technology, to promote authentic participation, to empower local groups and to encourage professional staff and extension systems figure prominently in development failures and successes. Thus, a central challenge to technicians, planners and policy-makers is to ensure that indicators and information address these issues.

The Sustainable Agriculture and Rural Development (SARD) framework

The four thematic areas of SARD (initially developed at the den Bosch Conference on Agriculture and the Environment (s' Hertogenbosch, the Netherlands, 15-19 April 1991) and subsequently incorporated as Chapter 14, Agenda 21), and their sub-elements provide a useful starting point for countries to think about their indicator priorities and information needs. The SARD framework includes:

1. Policy Adjustment and Planning Assistance:

; Agricultural policy analysis.
; Food security.

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; Forest use and management.
; Sustainable fisheries use and management.

2. Strengthening Human Resources and Institutional Capacity:

; Training and education.
; Nutrition and food quality.
; Development of rural households.
; Participation in rural development.

3. Improved Management of Natural Resources:

; Land conservation and rehabilitation.
; Efficient use of water resources.
; Animal genetic resources.
; Plant genetic resources.

4. Sound Use of Agricultural Inputs:

; Plant nutrition and soil fertility.
; Pest and pesticide management.
; Energy for rural development and agricultural productivity.
; Application and management of technology.

The integrated nature of sustainability

Indicators can be developed for each category of the SARD framework to measure the condition and trends in each critical sector. However, the challenge of sustainability (and the point that inhibits progress) is its three-dimensional nature (the environmental, the social and the economic) and the need to make trade-offs (e.g., between economic growth and environmental protection) and adjustments to maintain these three components in a dynamic balance. Although many would like to believe otherwise, win-win (all parties benefit) situations are not always possible. Invariably, someone or some group becomes disadvantaged from a policy change and resists the change.

Cutting across the three elements of sustainable development are issues which often determine how effective development interventions will be. These factors include:

; technology research and application;
; distortions in international trade;
; resource allocation (e.g., urban/rural investment and financing);
; population supporting capacity (e.g., natural resource endowments).

Institutional indicators

Although indicators of sustainable development pose an enormous challenge to develop, there are a number of entry points to begin work. For example, the governments of most countries already influence land use through their agriculture, forestry and fisheries policies and planning processes; they use various kinds of information to arrive at their decisions. But, traditional environmental indicators that focus on the use of pesticides and fertilizers, crop productivity, land conservation and so on, ignore human and institutional performance even though it is often the critical factor in success.

If SARD is seen primarily as a management challenge and not simply a technological or financial one, then some emphasis in indicator development should be on measuring the effectiveness of decentralization, setting unambiguous performance standards and involving stakeholders. This is quite different from the rather static “state” indicators which are often employed.

An approach being tried in Tanzania (Table 1) through a regional Global Environmental Facility (GEF) project, focuses on biological diversity and has developed a classification system and set of institutional indicators as indicated below.

TABLE 1
Institutional indicators developed for Tanzania

ISSUES	MEASURES
Management	Coordination mechanisms, Performance incentives, Levels of hierarchy
Finance	Resources dedicated to biodiversity - Control over allocation
Trained personnel	Training profile - Skills upgrading
Information	Exchange mechanisms - Monitoring and evaluation
Acceptability	Participating mechanisms - Decentralization
Accountability	Performance standards - Evaluation
Timeframe	Short-term - Long-term
Level	National, District - Village, Community, Eco-zone
Actors	International, National - Ministry, District, Village

Pressure-state-response framework

Many countries have national agricultural development plans which are developed on a three- or five-year rolling basis. These plans frequently use a policy analysis matrix to examine supply and demand conditions, prices, investment requirements, exchange rates, trade opportunities and other factors to achieve objectives such as economic growth, crop diversification, food security, poverty alleviation, income generation and/or nutrition objectives.

Goals and objectives are established (or the existing ones modified) that, at least nominally, are based on exploiting comparative advantage both within and between countries. This means that, *ceteris paribus*, a country or district with its unique endowment of natural resources, capital (machinery, services, infrastructure) and human resources, is able to produce a product more cheaply locally than it can import it. The converse is also true - the same country or district may find it cheaper to import a product than to produce it locally.

In determining comparative advantage, the natural resources base and its agro-ecological potential are critical but often underappreciated factors in determining the costs of production and productivity (yield/ha). Such values are usually considered only indirectly in the policy making or planning processes or not at all. Thus, a framework is needed that accommodates the full range of social, environmental and economic factors that enter the sustainability nexus.

The most widely adopted framework at present is referred to as pressure/state/response (Table 2) which was developed in the 1970s and is well suited to addressing the chain (filiere) of events that lead to environmental impacts.

TABLE 2
Example of pressure/state/response (PSR) framework.

ISSUE	PRESSURE (Driving force)	STATE (Resulting condition)	RESPONSE (Mitigative Action)
SOIL EROSION	Hillside farming	Declining yield	Terracing, perennial cropping
QUALITY WATER	Agro-industrial processing	Fish die-off	Water treatment, technology adjustment
CONDITION OF GRASSLAND	Livestock grazing	Soil erosion	Stock rotation, de-stocking revegetation

Pressure refers to the driving forces that create environmental impacts. They could include hillside farming, agro-industrial processing, livestock grazing, forest harvesting, etc.

State refers to the condition(s) that prevail when a pressure exists. This could be, for example, declining yields, fish die-off or soil erosion, etc.

Response refers to the mitigation action(s) and levers that could be applied to reduce or eliminate the impacts.

To avoid an overload of information and to make the PSR framework function effectively, indicators must be “issue driven”. Failure to do this results in the generation of too much information and lack of focus on the underlying forces that created the problem. At first glance this point seems obvious yet in much indicator work the demand for data is quite heavy. PSR is well adapted to an issues-oriented approach but is weaker when planning is required and a broader range of information is required, much of which is not issue-oriented (Table 3).

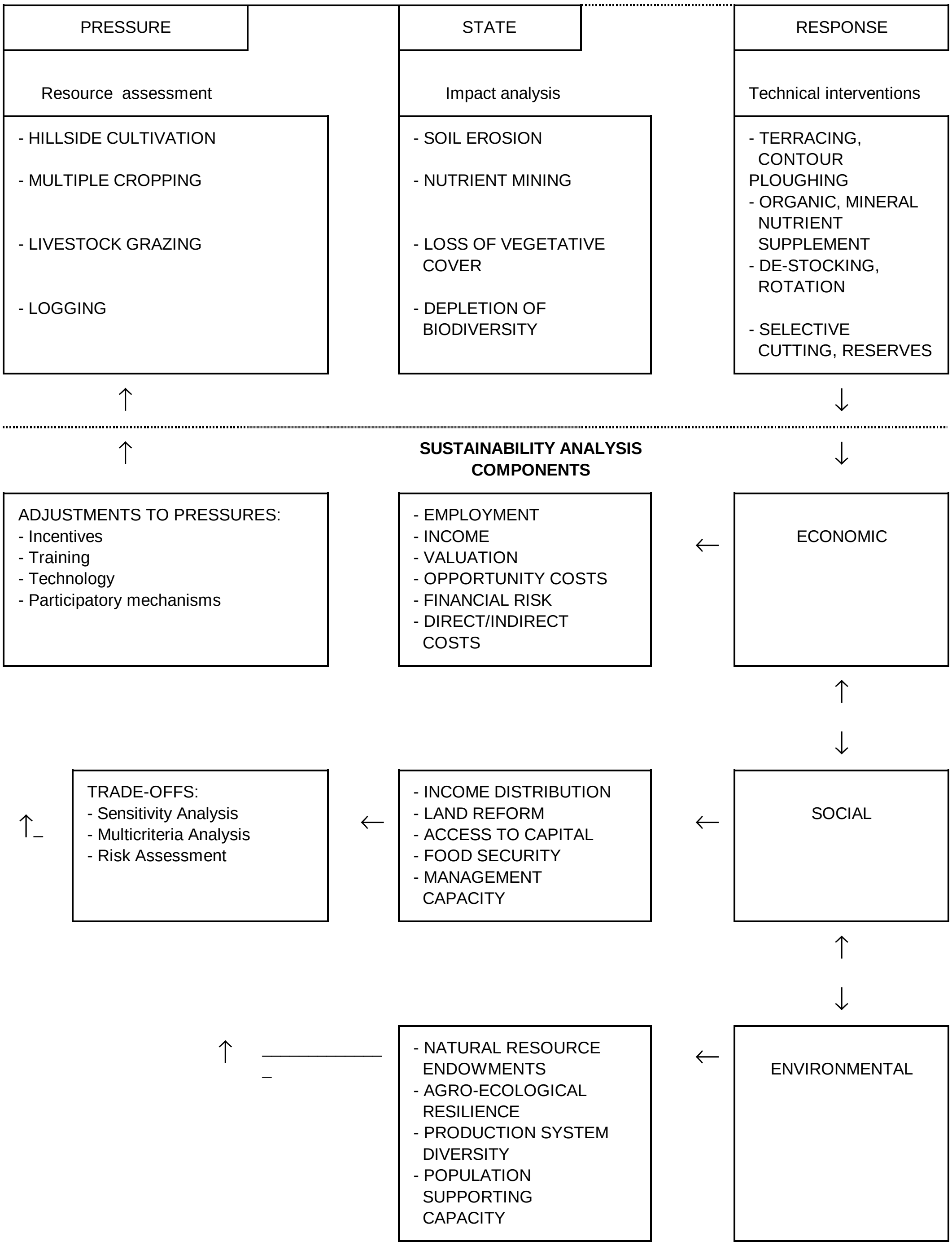
A shortcoming of the PSR vis-à-vis sustainability indicators and analysis is its inability to address the multiple dimensions of sustainability; it was originally designed by OECD to address environmental concerns. If SARD is about better management and making trade-offs between economic, social and environmental objectives and the PSR is accepted as the default analytical framework, then it must be complemented by a component that allows the user to identify linkages between the driving forces (e.g., subsistence income and hillside farming. See Figure 1).

TABLE 3
Placement of FAO Contributions to Agenda 21 Indicators in the driving force-state-response (DSR) framework

Chapter	Driving Force	State	Response
10. Planning and Management of Land Resources		* *land-use change* * land condition change#	
11. Combating Deforestation		* annual roundwood production**+** * forest growing stock**+** * forest area**+** * *wood as percentage of energy consumption***+** * forest area by natural forest area and plantation area	* deforestation rate**+** * reforestation rate**+** * forest harvesting intensity * managed forest area ratio * protected forest area as percentage of total forest land area##
12. Combatting Desertification and Drought	* *fuelwood consumption per caput* * drought frequency**+** * national annual rainfall index	* *livestock levels per km^2 in dryland***+** * greenleaf biomass * *population living below poverty line in drylands*	
13. Sustainable Mountain Development	* population dynamics of mountain areas	* welfare of mountain populations * assessment of the condition and sustainable use of natural resources in mountain areas	
14. Promoting Sustainable Agriculture and Rural Development	* *use of pesticides* * *use of fertilizers*	* arable land per caput * irrigated area as % of arable land * area affected by salinization and waterlogging * *agricultural research intensity ratio* * *agricultural extension funding* * *agricultural education* * energy source mix in rural households * energy use in agriculture * energy source mix in agriculture	
15. Conservation of Biological Diversity			
17. Protection of the Oceans, All Kinds of Seas and Coastal Areas		* catches of marine species**+** * ratio of current fishing effort to that at MSY * ratio of current fishing mortality rate to that at MSY * ratio of current population biomass to that at MSY * ratio of current biomass to that under virgin conditions * algae index * discharges of oil into coastal waters * releases of N and P to coastal waters	* participation in maritime treaties/ agreements

Note: indicators that could be placed in alternative DSR category or in more than one category are shown in italics.
\# Also relevant to Chapters 14 and 15 of Agenda 21.
\## Also relevant to Chapter 15 of Agenda 21.
+ These indicators are **not** recommended for retention.

FIGURE 1
Modified PSR framework for sustainability analysis.



N.B. The “Pressure and “State” boxes need not always be negative. As positive trade-offs from the sustainability analysis flow through the system, adjustments should become less extreme.

Environmental information

Information related to land suitability, pollution impacts and other sustainability considerations is available or can be estimated and included with the costs of production, revenues and the resulting profits which underpin the policy analysis framework. The results are not always as precise as would be desired but when decisions are being taken without any information, some data and an approach which can allow for incremental improvements in the quality of decision making can be more useful than no data at all. Indicators for land, water, soil, biodiversity and other factors can be used along with economic data by constructing scenarios based on available information after identifying gaps and assessing quality.

There is much evidence that agricultural policy is often biased against resource conservation and sustainable production practices. However, when the costs of deterioration in the natural resource base from inappropriate land use is calculated in farm income, resource conservation practices compete economically and financially with those that maximize income over the short and medium terms; the longer the time period, the more cost-effective are sustainability practices.

If governments use this information to make better policy choices, to identify failures and to make adjustments, the sector would be able (theoretically) to allocate resources more efficiently, increase profits margins and, keeping constant factors such as population, produce indefinitely.

Social information

Social factors such as landlessness, migration to engage in wage labour, land tenure, rural unemployment, access to credit or needed inputs, weak extension systems can all serve to undermine sustainable development. The challenge is to know when, to what extent, and under what conditions, these factors interact with economic and environmental factors to work against sustainability.

The Human Development Index (HDI), produced by UNDP, is one attempt (perhaps the most ambitious) to reflect an array of social and economic concerns in a single index. It combines per caput GDP with indicators of adult literacy and life expectancy to generate a weighted index of "essential" living standards.

However, essential living standards will vary among countries and regions. How should questions of equity, freedom, health, food security be reflected in a modified HDI? And, how should they be weighted?

Economic information

Policies with respect to trade, spending, exchange rates, labour markets, and inputs are included in the analysis and impinge on the natural resources base. Policy objectives are realized through the introduction of new technologies, diversifying or specializing production which raises or lowers prices for consumers or producers, through taxes, restrictions, subsidies, guarantees, and income supplements.

Policy failures, from the point of view of sustainable development, arise when instruments inadvertently lead to misuse of natural resources. Whereas a government objective may be to increase production of a commodity, such as soybeans or coffee or cotton in order to generate foreign exchange, and the policy instrument used is favourable credit terms or price guarantees, an unforseen result may be increased soil erosion, mining of soil nutrients, misuse of pesticides or fertilizers, or a variety of negative impacts that represent long-term costs to the government and, especially, to the producer.

These externalities or indirect costs are seldom calculated or even identified in policy analysis and planning even though they may create direct costs to the agriculture sector and reduce the GDP of a country. As a general rule indirect costs and externalities should be included in economic planning and analysis to the extent that the benefits obtained be equal or exceed the costs of obtaining them. Thus the ability to accurately value such costs and benefits looms large in the economic component of sustainability analysis.

Criteria for indicator development

Many professionals agree that at least three criteria should guide the development of sustainability indicators:

1. Policy relevance - to ensure the indicators address issues of primary concern to a country or district and receive the highest priority. In some cases policy-makers may already share concern about an aspect of sustainability (e.g., land degradation) and be ready to use indicator information for addressing the issue; in other cases (e.g., biodiversity) it may seem unclear what is needed and thus indicators will have to be used in a way to raise awareness and promote action.

2. Predictability - to allow a forward looking perspective that can promote planning and decisions on issues before they become too severe. Anticipatory decision making is at least as important to sustainable agriculture as is recognition of existing problems.

3. Measurability - to allow planners and analysts the means to assess how the indicator was derived, either qualitatively or quantitatively, and decide how it can best be applied in the planning and decision-making process. Given the limited information on environmental conditions in many countries, qualitative measures such as rapid appraisals, informal surveys and opinion polls have an important role to play. They can be useful in policy making despite a bias for traditional statistical measures.

Aggregating data and information

Although in the political sphere, time horizons may be short, experience in a number of countries shows that:

1. politicians can and often do use a wide array of information in arriving at their position;

2. their positions change as new information becomes available; and

3. their information comes from a wide array of formal and informal sources.

Thus, the temptation to arrive at single digit indicators or to produce indices that aggregate a number of weighted indicators (the correlations for which are seldom known) should be avoided in the early stages of indicator development. More effort and trials are needed, as has been done in the Netherlands, to experiment with menus of indicators that are thematically linked to represent several dimensions of an issue such as overgrazing or deforestation.

For example, land degradation could arise from unemployment, insecure land tenure, food insecurity, population pressure, cropping practices or other factors. In most cases it will be a combination of factors and each country must identify the key ones for their situation. This paper emphasizes the role of indicators in promoting sustainable development at the national and sub-national levels, but some groups are calling for indicators to monitor progress in implementing the Agenda 21 at the global level. They are interested in issues such as biological diversity, climate change, international waters, toxic chemicals, etc.

The Scientific Committee on Protection of the Environment (SCOPE) has devised a sustainability matrix (below) comprised of "a series of well known and internationally accepted indices for economic and social factors"; augmented by environmental indices. Clearly, many OECD countries would recognize the elements, but would it be in the interests of, for example Tanzania or Peru or Papua New Guinea to be included in such a matrix? If not for global, then for regional purposes? Would the SCOPE measures be the appropriate ones, for example, in the East African region? Would it make any difference?

TABLE 4
SCOPE - Sustainability matrix.

Environment	Social	Economic
Source index	Unemployment index	Economic growth (GDP)
Sink index	Poverty index	Saving rate
Life support index	Shelter index	Balance of payments
Human impact index	Human capital index	National debt

For reporting at the global level, groups such as the Commission on Sustainable Development (CSD) would prefer a small number of indicators. For example to monitor progress in agriculture, four to eight indicators are foreseen. However, there are many ways to measure soil erosion, land degradation and other factors. The individual measures cannot always be added together to arrive at a globally or regionally meaningful number.

Notwithstanding the risks in using aggregated indicators, there are also risks in using too many individual indicators. One is the failure to demonstrate a clear trend or condition. A large selection of indicators can also lead some decision-makers to select one that supports their particular view. It can also cause confusion in sorting out what is considered the most relevant information. This can stop or delay the decision-making process and reinforce bureaucratic inertia.

Constraints on existing information

At present statistical data are available only for national boundaries which limits their usefulness in determining net production potential and population supporting capacity and very few of them are geographically referenced. Therefore, a requirement for improving the usefulness of indicators is the need to organize sub-national data in an agro-ecological-zone format which can overlay district boundaries. On this basis, environmental, social and economic constraints in countries and districts can be assessed in the context of population supporting capacity. Although this work has been undertaken in some countries, it lags far behind the need. An agro-ecological-zone-based information system could also include information on waterlogging and salinity, loss of forest cover, presence of plant and animal genetic material, and prevalence of vector-borne disease, land tenure, food security, energy and other factors which figure strongly in sustainability analysis.

Crossing the threshold

The last constraint to the use of indicators for sustainability analysis is the poor understanding and lack of consensus among technical experts of how economic, social and environmental forces interact. There are numerous cases where high levels of soil erosion have existed for long periods either without significant loss in productivity or not enough loss to induce the farmer to change behaviour. Thus, it seems that one could not state unequivocally that soil erosion is an indicator of unsustainability unless a link was established demonstrating substantial economic and/or social effects.

Despite scientific uncertainty, the use of thresholds which provide a range of allowable degradation under specified conditions could be important tools for planning and monitoring sustainability performance. For example, most agro-ecological zones have information on soil type, climate, topography and land suitability for various crops. When an erosion rate is known, experts familiar with the region can estimate whether the erosion rate is sustainable under a given cropping regime. Based on past experience, training and intuition, such rule-of-thumb estimates constitute expert systems that, if organized systematically, could be used by planners and analysts.

Once planners, policy-makers and land users agree on the issues to measure, criteria for a threshold table can be established for social and economic aspects based on cost effectiveness factors such as time, expense and level of detail involved. In many cases, rule-of-thumb measures are a practical way to begin. Two important elements in such a process are: a) the use of participatory mechanisms, and b) to state clearly the criteria used in calculating an indicator.

These aspects are an important means of promoting transparency and dialogue in the planning process. If a person or group knows the assumptions and methods used in developing an indicator, even if they disagree with the method or the result, an open and flexible process can become the basis for dialogue and adjustment.

In most cases no single indicator would determine sustainability or unsustainability. However, a series of indicators that collectively exceed the threshold levels should be sufficient cause to investigate data quality, conduct a rapid survey of the area involved, consult knowledgable experts, or all of the above.

CONCLUSIONS

This paper has reviewed a number of the constraints to indicators but also strived to avoid the impression that nothing can or should be done. The main points are the following:

1. Development of sustainability indicators must be closely tied to the development of national and sub-national information systems for agricultural planning and programming.

2. Initially, the emphasis should be on improving national and regional capacity with regard to data collection and information collection; barring this, global indicators will have little meaning.

3. Aggregation of existing data to derive global indicators without addressing data quality would likely lead to inefficient allocation of resources and misunderstanding of local forces and influences that underlie unsustainable development practices. However such exercises might be usefully carried out on a regional basis (e.g. Africa, Asia, Latin America) or among countries with a number of common characteristics (e.g., OECD, small island states).

4. Thresholds and targets are useful means of allowing countries to compare their performance, for example in controlling soil erosion, against internationally accepted norms based on local natural resource endowments and land-use practices.

5. Basic data and information regarding production potential and supporting capacity should be organized based on agro-ecological zone and overlaid with national or district boundaries.

6. Interactions among the environmental, social and economic components of sustainability need considerable field research to better understand how they affect each other and the driving forces that need to be measured.

7. Human and institutional capacity to manage the development process through participatory and transparent approaches is fundamental to sustainable agriculture. Indicators to monitor these dimensions are essential but extremely difficult to collect; more emphasis is needed in this area.

8. An important albeit indirect goal of indicators is greater participation and transparency in the planning and programming process in countries. Without this, even the best data and analysis will not lead to sustainable development as it was conceived at UNCED.