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NATURAL RESOURCE AND SUSTAINABILITY MONITORING

A Conceptual Framework, Issues and Challenges

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ABSTRACT

Periodic monitoring of the status of natural resources is fundamental to generate adequate information for planning and policymaking towards their sustainable management. This paper provides an overview of the concepts, issues, and challenges that planners and policymakers face in designing natural resource and sustainability monitoring systems and using their outcome in the formulation of policies and intervention programs.

Using a conceptual framework based on the concept of resource management domains, the principles involved in various types of monitoring systems are outlined after a brief review of their objectives. This is followed by a description of necessary steps in implementing a monitoring system and possible flows of information and its use in various stages of decisionmaking. Identifying relevant issues in designing different types of natural resource monitoring, future challenges facing governments, academic institutions and donor agencies in developing sustainable monitoring systems are discussed. Presenting some leading research issues in improving the design and implementation of natural resource and sustainability monitoring, guidelines for evaluating their performances in meeting the objectives of improved policymaking and reduced natural resource degradation are also discussed. The paper concludes that a monitoring system which is simple, user-driven, based on existing institutional structures which increases the capacity for analysis and interpretation and has the commitment of relevant decisionmakers for using the information in policy design and program development is more likely to be sustainable and successful.

Keywords -- Natural resources, sustainability, monitoring, planning and policymaking

NATURAL RESOURCE AND SUSTAINABILITY MONITORING
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INTRODUCTION

Periodic monitoring of changes in the conditions of natural resources and their sustainable use is fundamental to generate information for planning and policymaking. Natural resource and sustainability monitoring (NRSM) is undertaken to provide timely and relevant information to enable policymakers and program managers in formulating prudent policies and implementing effective interventions to reduce degradation of natural resource base and improve its sustainable use over time. Natural resource monitoring has been implemented in a number of developing countries for the past two decades with various objectives and under various names, but without much success. Poor understanding of the principles, inappropriately designed monitoring systems, combining several objectives, ill-defined indicators, operational inefficiencies in implementation, and limited capacity to convert information into specific policies and intervention programs are among the reasons provided for such a dismal picture (Hassan and Hutchinson, 1992).

A major objective of this paper is to develop a conceptual framework for designing and implementing NRSM systems. It is also useful to address the ever-changing terminology used to describe monitoring systems which have continued to adapt to particular information needs of different country, sector, and program situations. Although the concept of monitoring environmental change has been developed and used in various related fields for several decades (Vieira, 1985; Clarke, 1986; Cartledge, 1992), the Earth Summit of 1992 renewed the interests of the governments in monitoring

changes in the conditions of natural resources as an input to policy decisionmaking (The World Bank, 1995). The Earth Summit which recognized that "sustainable development requires availability of accurate and timely information to help decisionmakers and the general public make sound decisions (p. 108)" also provided major impetus for monitoring sustainable use of natural resources (UNCED, 1992).

The Agenda 21--program of action for sustainable development of the Earth Summit declaration identified two major program areas to be implemented to ensure that environmental and natural resource management decisions are based on sound information--bridging the existing data gap on the status and changing conditions of natural resources and improving information availability for intervention programs and policies. Development of appropriate indicators of sustainable development, promotion of global use of these indicators, improvement of data collection systems and their use, improvement of data assessment and analysis systems and production of information usable for decisionmaking by improving the timely availability of information are among the specific activities recommended for achieving the objectives of these program areas (UNCED, 1993).

This paper addresses issues relating to the monitoring of natural resources in order to improve their conservation and management for sustainable development. Particular attention is given to the natural resource management issues that directly impinge upon the welfare of the population through increasing food security, reducing malnutrition and poverty, and improving the sustainability of food, fuel and fiber production systems. For the purposes of this paper, *Natural Resource and Sustainability Monitoring could be defined as a process of monitoring, analysis, and interpretation of indicators and causal factors associated with the management of natural resources and their sustainable use in order to make appropriate decisions that will lead to effective interventions which result in improvements in conservation, management, and productivity of natural resources.*

The need for and the nature of natural resource and sustainability monitoring efforts generally differ from one country to another. Even with well-designed monitoring

systems in place, there is no guarantee that the information generated will be used fully in the process of decisionmaking. As a consequence, these monitoring systems tend to remain as data collection exercises. Such low use of information militate against the sustainability of the already existing monitoring systems in several developing countries. Further, these monitoring exercises are confined to narrowly defined environmental projects without giving due consideration to the inter-related role of factors that influence the sustainable use of natural resources (Rawlings, 1994).

The purpose of this paper is to provide an overview of the concepts, issues and challenges that planners and policymakers face in designing natural resource and sustainability monitoring systems and using their outcome in the formulation of policies and intervention programs. Identifying various issues and problems of natural resource management, this paper uses the concept of resource management domains to develop a conceptual framework for natural resource and sustainability monitoring. After a review of various emerging objectives of natural resource and sustainability monitoring, the principles involved in various types of monitoring systems are outlined. This is followed by a description of necessary steps in implementing a monitoring system and possible flows of information and its use in various stages of decisionmaking. Identifying relevant issues in designing different types of monitoring systems, future challenges facing governments, academic institutions and donor agencies in developing sustainable systems of natural resource and sustainability monitoring in developing countries are discussed.

Presenting some leading research issues in improving the future design and implementation of natural resource and sustainability monitoring in developing countries, the guidelines for evaluating their performances in meeting the objectives of improved policymaking that may lead to better management of natural resources are also discussed. The paper concludes that a monitoring system which is simple, user-driven, based on existing institutional structures which increases the capacity for analysis and interpretation, and has the commitment of relevant decisionmakers for using the information in policy design is more likely to be sustainable and successful.

A CONCEPTUAL FRAMEWORK FOR NATURAL RESOURCE AND SUSTAINABILITY MONITORING

This paper uses the concept of resource management domains (RMDs) in order to identify and classify major issues and problems that warrant monitoring the conditions and changes in various natural resources and their sustainable use. *A resource management domain is defined as a spatial unit (landscape) that offers opportunities for identification of problems, analysis of alternative solutions and application of resource management options to address specific issues in order to increase the sustainable use of one or more resources.* The concept of RMD is derived from geo-referenced biophysical and socio-economic information which involves dynamic and multi-scale concepts both in terms of the number of resources and the level of their use, and reflects several dimensions of human interventions in the landscape (Turnbull, 1996).

The RMD framework provides better approach to defining natural resource issues than other traditional approaches such as classifying natural resource problems by agro-ecological zone. First, it provides a multi-disciplinary focus to the natural resource problems that may spill over several agro-ecological zones (Conant et al., 1983). Second, it attempts to remove the notion that working with agro-ecological framework is the sole domain of agronomists and biological scientists. Multi-dimensional resource problems both in space and time can be handled through the RMD approach on a regional basis without losing focus on a particular resource issue (Dixon, 1989). Third, the RMD approach is better amenable for developing and organizing data bases which can be used for monitoring and assessing nature and use of natural resources. Finally, data sets developed for a particular RMD can be made flexible and can respond easily to tailor solutions to specific issues and problems.

Identification of natural resource problems and issues related to their sustainable use provides an opportunity to specify information needs for resource monitoring and management. It also helps, depending on the objective of monitoring, to design appropriate information generation systems. Further, identifying major issues and problems under each RMD enables a better development and choice of indicators of monitoring. Table 1 presents an overview of major issues and problems faced in sustainable use of various natural resources by RMDs[2].

Several resource components interact with each other in a particular RMD. In an irrigated agricultural system, for example, availability and use of water resources has implications for productivity of soil through the process of salinization and waterlogging (Jaglan and Qureshi, 1996; Babu et al., 1996). Further intensive use of agro-chemicals may have deleterious effects on groundwater resources and on biodiversity of natural predators of pests (Babu, et al., 1992; Naylor, 1994). Similarly, in the semi-arid tropical zones, continued monocropping without proper replenishment of soil nutrients may reduce the productive capacity of the soil resulting in increased fragility of these soils (Sivanappan, 1995). Due to the rainfed nature of crop production, recurrent droughts exacerbate the conditions of low land quality. In the forest margin areas, overgrazing and destruction of vegetative cover through deforestation increase the exposure of land resources to gradual process of desertification (Kaimowitz, 1996).

Competing uses for land in the buffer zones have important implications for land use and protecting the forest cover (Skonhobt and Solstad, 1996). The biodiversity of flora and fauna are threatened due to the expansion of crop and livestock production in the buffer zones (World Bank, 1995). In the fragile ecosystems such as the mangrove forests, destruction of the mangrove forests for fuel and expansion of shrimp production has resulted in deterioration of water quality and depletion of fish stock which the local population has depended for food security (Dewalt et al., 1996). In the mountain environments, deforestation results in flooding which furthermore contributes to soil

erosion, sedimentation, and mass wasting resulting in low quality and quantity of land for crop production (Metz, 1991).

It is becoming increasingly clear that monitoring a specific set of natural resources without identifying the causal factors that contribute to their change will not be adequate for planning and policy purposes. The indicators developed for monitoring a particular resource component may be used as a causal factor in explaining the status of other resource components in a resource management domain. Thus, monitoring a RMD provides a holistic approach for devising appropriate policies considering the interactions of inter-related resources.

Each of the broad categories of RDMs can be further classified for monitoring purposes. For example, in the rangelands/grazing systems the monitoring systems should be appropriately modified based on the following characteristics: Savannas with tall grasses, deciduous forests with high grasses, desert shrubs, seasonally flooded vegetation, tropical rainforests, winter rainfall vegetation, and montane forests. Since the key management problems and recommended practices will differ based on these characteristics, the indicators for monitoring would also vary among these categories (Child et al., 1984). Although resource management domains are generally defined within a specific geographical region, they may cross national and regional boundaries. Recent work on the development of land quality indicators for moist-tropical savannas, intensively irrigated areas, and overgrazed pastoral zones reflects an attempt towards such an approach (The World Bank, 1995).

Based on the concept of the RMD, a brief outline of a conceptual framework for information generation through natural resources and sustainability monitoring is developed below. Such a framework is useful as a guideline in identifying important indicator variables and evaluating the need for collecting data on them. In general, the choice of indicators for information generation depends on the objectives of natural resource and sustainability monitoring, policy analysis needs, different levels of planning, existing infrastructure for data collection, and the capacity to analyze and interpret data.

To meet the information needs and identify variables for data collection, a conceptual framework for selecting variables in monitoring natural resource and sustainability is given in figure 1. The general objective of the natural resource and sustainability monitoring system is to generate timely information on the status of natural resources and their sustainable use so that policy, program, and management interventions could be undertaken. The major natural resource domains that are to be monitored for enhancing their sustainable management are given on the left most end of the figure[3]. They include for example, irrigated agricultural systems, semiarid lands, forest margins, watersheds, and fragile ecosystems. The issues, problems, and themes that are to be addressed in these domains and the appropriate indicators are identified next to them. The role of natural resource and sustainability monitoring is central to the planning and policymaking for sustainable natural resource use. A natural resource and sustainability monitoring system plays two distinct roles: conversion of information into data which can be processed and analyzed, and conversion of data into policy and planning relevant information for the use of decisionmaking systems. Various users and decisionmaking groups are identified at the extreme right of the figure.

The design of the monitoring system will depend on user needs and purposes for which information is used. Information generated, based on this conceptual framework, can be used to assist planners and policymakers in preparing a wide range of interventions--short-term contingency plans to long-term policy interventions to improve the sustainable use of natural resources.

TYPES AND OBJECTIVES OF THE NATURAL RESOURCE AND SUSTAINABILITY MONITORING SYSTEMS

Several systems of monitoring natural resources have been developed over the years with various objectives and approaches. Ecologists have for long used several methods of monitoring changes in various ecological systems with particular attention to specific species and their habitats (Clarke, 1986; Treweek, 1995). As part of assessing

the impact of development projects on the environment, various monitoring procedures have been developed under Environmental Impact Assessment (Canter, 1996). Using the analytical procedures for studying relationships between organisms and their environment, ecologists have also attempted to incorporate ecological inputs in environmental impact assessment procedures (Treweek, 1996). Recently, assessing the ex-ante and ex-post impacts of development projects on the conditions of and the changes in the environment has been given emphasis (World Bank, 1991; Saddler, 1994).

Methods for development of natural resource inventories and documenting baseline information on the status and trends in use of natural resources have been developed and are in wide use in developing countries (Conant, et al., 1983). Soil surveys and land evaluation methods have formed major approaches to monitoring the changes in the conditions of soils and their productive capacity (Bie and Lamp, 1981; Bie, 1990, Sanders, 1991). To help understand the impact of new technologies and evaluate them for their contribution towards improved use of land resources, land information management systems have been developed for developing countries (Dale and McLaughlin, 1988). In order to monitor the forest cover, remote sensing systems have been used to generate satellite images (Haack and English, 1996; Falloux, 1989) which further have been used in developing geographical information systems (Cook and Norman, 1996; Burrough, 1986). Remote sensing techniques developed for monitoring natural resources at a national level have also been applied to understand changes in resource use at the farm level (Hutchinson, 1991). Information systems that are useful in environmental and natural resource appraisals have been increasingly used for designing agricultural and land development projects (Petermann, 1996). Monitoring improvement or deterioration of the conditions of natural resources has also been an important component of designing monitoring and evaluation systems of natural resource projects (Kakonge, 1995; Edwards-Jones and Gough, 1994; FAO, 1985). Researchers, in the process of developing impact assessment procedures, have also focused on designing monitoring systems that provide information for evaluating the impact of projects on natural resource base (Lawrence, 1991; Leistritz, et al., 1993).

Recently several approaches have been proposed for assessing the sustainability of natural resource use (Becker, 1997). Information on modified gross national product which incorporates the value of depreciation of natural resources, changes in total factor productivity and willingness to pay for various resource use through contingent valuation, hedonic price or travel cost approaches constitutes the economic approach to assessing sustainability (Pearce, et al., 1990; Lynam and Herdt, 1989; Winter-Nelson, 1995). Indicators of conditions of natural resource base which reflect land quality, (Pieri et al., 1995), biological diversity (Gaston, 1996), and sustainability of production systems (Ehui and Spencer, 1990; Izac and Swift, 1994; Becker, 1995) have also been developed.

Monitoring environmental progress has been the major international outcome that followed the Earth Summit. Efforts have been made to develop preliminary indicators which could be used by various resource management systems such as forest management indicators, biodiversity indicators, and poverty indicators (World Bank, 1995). Information on these indicators could be effectively used to assess resource use efficiency and the role of taxes and subsidies to improve the sustainable use of natural resources. Additionally, it would also be useful to analyze the impact of economy-wide policy on changes in the conditions of natural resources (World Bank, 1994). However, little progress has been made to understand the nature and extent to which already existing information collection systems contribute to the generation of information for environmental and natural resource programming and policymaking. While further research is needed to improve and refine these concepts and indicators, approaches to develop systems of natural resource and sustainability monitoring and using them for planning and policymaking have been rudimentary at best[4].

While several systems of gathering information on the status of natural resources have been in operation in several developing countries with various objectives, there has not been adequate coordination of these efforts in order to generate useful information for planning and policymaking purposes (Hassan and Hutchinson, 1992). Given the limited resources for designing and maintaining operational systems of natural resource monitoring in developing countries, there is a need for combining existing efforts through

a full understanding of various planning and policymaking objectives in the natural resource sector[5]. Based on the above review of the purposes of various monitoring systems, an approximate classification of natural resource and sustainability monitoring can be developed.

The classification of environmental and natural resource monitoring systems has expanded over the years to include new types of information systems based on emerging needs in information generation and use (Munasinghe and Shearer, 1995). Depending on the purpose for which information on natural resource and sustainability was generated and the time involved in planning, monitoring systems could be classified into five major types. For short-term planning in rationalizing and maximizing the impact of intervention programs, the monitoring system for ***program management*** is suggested; to undertake long-term development plans and sectoral policies with enhanced sustainability outcomes, the monitoring system for ***natural resource planning and policy design*** is conceptualized; to meet the needs of emergency planning and prevent short-term critical impact of natural resource degradation, the monitoring system for ***early warning and intervention*** is proposed; in order to assess and monitor the indicators of sustainability as a basis for managing natural resources and to flag-off a particular resource problem, a system of monitoring for ***problem identification and advocacy*** is recommended. While these systems are designed to play specific roles in meeting information needs, information generated through one system could also be used for other objectives of monitoring.

More recently, several developing countries and particularly countries in sub-Saharan Africa have been implementing structural adjustment policies and programs which may have deleterious effects on some sections of the population, at least in the short-run (Munasinghe, et al., 1993). This in-turn influences the pattern of use of natural resources and their sustainability (Maler and Munasinghe, 1996). To monitor the impact of such economy-wide policies on the use of natural resources and to provide feed back to policymakers, a system of ***monitoring the effects of economy-wide policies*** is suggested. While the objectives towards which these systems of natural resource and sustainability

monitoring provide information are equally important, it is extremely difficult to meet all these objectives through a single monitoring system. Thus, there exists a need for identifying and implementing a methodology of monitoring natural resource base and its sustainability which could be modified and fine-tuned to meet the information needs of different objectives. A summary of various types of natural resource and sustainability monitoring systems, as described above, is depicted with their associated objectives in figure 2. A brief description of each system is given below.

Natural resource and sustainability monitoring for program management: This is designed to assist program managers, administrators and donor agencies in the operation and evaluation of on-going natural resource intervention programs. Information generated in this type of monitoring system is useful in decisionmaking on modifying, redesigning and continuation of intervention programs. In addition, this type of monitoring includes evaluation of the actual impact of the intervention programs on the conditions of the natural resource base (Edwards-Jones and Gough, 1994). While a majority of the programs that use natural resource and sustainability monitoring for program management and evaluation in the past, have been in forestry and natural resource sector (Gregerson et al., 1989; FAO, 1985), agricultural programs such as small-scale irrigation schemes, commercial cropping, and other agricultural based income generating schemes increasingly use this type of monitoring for management and evaluation (Altieri, 1988; Smith and Plucknett, 1995). Lusigi (1995) presents a case study of Integrated Planning of Arid Lands (IPAL) project in Kenya, and demonstrates the development and use of natural resource and sustainability monitoring for program management.

Natural resource and sustainability monitoring for planning and policy design: Natural resource and sustainability monitoring for the purpose of development planning and policy interventions addresses information needs of planners, policy analysts, and policy decisionmakers at the RMD, local, regional, and national level. While information is generated largely by one or two sectors such as forestry, fisheries, and lands it is used also by national planning agencies and policy analysis units (Crowards,

1996; Winter-Nelson, 1995). Emergency, short, medium, and long-term policy alternatives are analyzed using data from this system to design appropriate interventions (De Almeida and Uhl, 1995). Data are also used to evaluate the impact of sectoral policies and programs on natural resource use (Heath and Binswanger, 1996). Using a wide range of data sources, but essentially through primary data collection methods, the system attempts to target resources to environmental hotspots and fragile resource management domains within a country (Warner, 1996). More decentralized approaches are possible with the use of natural resource and sustainability monitoring for development planning and designing policy interventions. Outcomes of this type of monitoring system include quantification of natural resource base on a national basis for national income accounting, analysis of causal factors for policy design, environmental impact assessment of various policy alternatives and programs to address resource problems, and design and target specific intervention strategies (Zhao et al., 1991). A review of natural resource and sustainability monitoring for planning and policy interventions in the context of environmental impact assessment is given by Treweek (1996).

Natural resource and sustainability monitoring for early warning and intervention: Monitoring natural resource and sustainability status to inform planners of impending emergencies at national and local levels is the main objective of this system. It is more useful in countries that are faced with periodic droughts and famines caused by changes in natural resource base and its use. It is also useful where food and war emergencies displace people and exert undue pressure on the sustainability of natural resources (Babu and Hassan, 1995). By monitoring appropriate indicators of natural resource and sustainability at local, regional, and national levels, information is provided in advance to decisionmakers to intervene with emergency assistance. Agriculture continues to be the major sector in several developing countries for this purpose which collects information on the food production and rainfall through its extension system, although the information is shared by national planning agencies, drought management units, district level offices, and food aid distribution mechanisms. A successful example of implementing natural resource and sustainability monitoring for early warning with

special reference to food security in Africa has been documented by Hutchinson et al. (1992). Monitoring systems that use remote sensing techniques for generation of information on land cover are well suited for early warning purposes (Haack and English, 1996). Information systems that address cadastral problems related to land resources are best organized to meet this objective (Dale and Mclaughlin, 1988). Unruh (1993) and Watkins et al. (1997) provide examples of situations where monitoring natural resources for early warning of resource degradation would help in reversing the trend.

Natural resource and sustainability monitoring for problem identification and advocacy: Generating information on specific natural resource degradation problems and quantifying them are the major focus of this system. The information needs are minimum for this system which generally includes specific natural resource and sustainability outcomes. In addition to identifying the problems, measuring their impact, and the number of people affected, information from this system is also used for sensitizing the public and decision makers in the government and donor communities. Increasingly, it is felt that this objective of natural resource and sustainability monitoring should be integrated with planning and policy design objective or program management objective so that the capacity created for these systems could also be used for problem identification. However, initiating this type of natural resource and sustainability monitoring system could be a precursor for designing other types of systems based on it. Angelson (1995), Dewalt et al. (1996), Gibson and Marks (1995), White and Runge (1995), and Tomich (1992) report incidences of natural resource problems where this type of monitoring would be most useful. Indigenous institutions and the local communities could be trained in designing this system for better identification of locality-specific natural resource problems (Appiah-Opuku and Mulanmoottill, 1997). However, involving communities in assessing their own resources through participatory processes has some limitations, partly due to the divergence of views on what constitutes resource degradation (Kakonge, 1996). Sanders (1991) provides a comprehensive review of international efforts to monitor specific problems of soil degradation in order to identify vulnerable and fragile areas that require immediate attention and intervention.

Monitoring impact of economy-wide policies on natural resources and sustainability: Designed to monitor possible negative effects of economy-wide policies such as structural adjustment and stabilization policies, this system also fits in very well with systems initiated for planning and policymaking, and program management. Although it does not require a separate system and could use information generated by systems with other objectives, this system helps to design programs to protect the vulnerable natural resource bases and to prevent short-term negative effects of policy reforms. Identifying the impact of policy alternatives on priority natural resource issues and their critical environmental policy links is possible through the collection of information through this system (Munasinghe, et al., 1993; Pearce and Warford, 1993). Like the system for problem identification, it could form the impetus for expanded systems for natural resource and sustainability monitoring in countries where no monitoring system currently exists.

METHODOLOGY OF NATURAL RESOURCE AND SUSTAINABILITY MONITORING[6]

Based on the general principles of monitoring and evaluation and the experiences gained from other disciplines and in several developing countries, a general methodology of natural resource and sustainability monitoring could be developed (Rawlings, 1994; Babu and Pinstrup-Andersen, 1994). An overview of the methodology of natural resource and sustainability monitoring which could be modified for different objectives, varying information needs and resource availability is presented in this section in two parts. First, a general methodological framework to be followed in designing natural resource and sustainability monitoring system is given. Second, the stages of implementing natural resource and sustainability monitoring with emphasis on data collection systems and modalities of converting information into policies and programs are described.

A general methodology of natural resource and sustainability monitoring is presented in figure 3. The overall objective of any system of natural resource and sustainability monitoring is the provision of timely information for interventions to improve the productivity of the natural resource base and its sustainability use by population. To accomplish this objective, it is important, as a first step, to assess the natural resource situation at national, regional, community, resource management domain, and farm levels. Such an assessment should be accompanied by diagnosing the causal factors that are responsible for changes in the natural resource base. The next step in the methodology is to identify the biophysical and socio-economic constraints that impede changes in the causal factors that will enhance the natural resource base and increase its sustainability.

Once these constraints are identified, alternative plans, policies, and programs could be analyzed for their potential impact in altering the potential path of natural resource use over time. In developing countries in general, such an analysis has been done with limited or no information on the existing situation and the associated causal factors. Also, it is well recognized that failure to explicitly and correctly identify the factors that cause natural resource degradation may result in designing erroneous policies and programs (Bradley, 1994). Hence, for efficient analysis of intervention policies and programs, adequate data on the indicators of the status and changes in natural resource base and their causal factors are a prerequisite.

The intervention policies and programs that are identified require an action plan for implementation. It is generally suggested that natural resource management policies and programs which attempt to change the biophysical base and productivity of the resource management domains should be introduced on a pilot scale and evaluated for their actual benefits before they could be implemented at a national level. However, the situation of drastic climatic changes and the associated reduction in the sustainability of natural resources which require immediate interventions, may not allow for detailed evaluation before large-scale implementation. Intervention policies and programs, either of emergency or of a long-term nature, should be evaluated for the benefits and costs of

improving the natural resource base on which the livelihood of the population depends. Based on the analysis of such information, the status of the natural resource base and its causal factors could be further studied and the intervention strategies could be modified. As mentioned earlier, the design of natural resource and sustainability monitoring and the time involved in assessing the situation and realizing the impact of policy interventions could vary depending on the specific purpose for which it is undertaken. However, the methodology presented here is common to different types of natural resource and sustainability monitoring systems discussed earlier.

Stages in implementing natural resource and sustainability monitoring: In following the general methodology presented above, several stages of implementing natural resource and sustainability monitoring should be recognized. It is not difficult to find monitoring systems in developing countries which are viewed merely as data collection mechanisms (Lusigi, 1995). This is largely because the process of data collection tends to become a goal in itself rather than a means of providing information for decisionmaking. A good understanding of the process of natural resource and sustainability monitoring is essential for its successful implementation. Various stages of implementing natural resource and sustainability monitoring are given in figure 4 and is briefly described below.

***Situation analysis and identifying the decision points*:** Before initiating a system of natural resource and sustainability monitoring, it is essential to identify the nature and types of resource management domains that are to be addressed. A broad definition of the problems in each natural resource domain is generally useful in specifying information needs and the level of monitoring. It also helps to identify potential decision points and decisionmakers for the use of information. For example, various indicators that reflect the status and change in the natural resource base need to be identified. It is also important to specify information needs based on the geographical location of the resource management domain. Specific characteristics of the resources such as soil, water, forest cover, and biodiversity should be broadly defined. The need for

information to be generated and compiled at national, sectoral, community, resource management domain, and farm levels should also be identified.

Identifying the nature and the scope of natural resource and sustainability problems, recognizing various types of decisions and levels at which they are made and specifying information needs to meet the demand of these decision points also help in the choice of appropriate system of natural resource and sustainability monitoring (D'Elia, 1995).

***Institutional structure for natural resource and sustainability monitoring*:** Major institutional structures that are needed for successful implementation of natural resource and sustainability monitoring could be classified into four categories: institutions involved in data and information generation; in data processing and analysis; in relating results of analysis to programs and policies; and in intervention decisionmaking. In most of the countries, the data pertaining to the indicators of sustainability which may reflect the status of natural resources (Becker, 1997) and their casual factors are collected through a lead sector or institution such as the Ministry of Natural Resources, Agriculture, Forestry or Wildlife. In deciding the choice of the institution for information generation, it is important to recognize the infrastructural network of institutions that could have a wider coverage so that information could be obtained from all regions of the country. This is particularly essential when the objective of monitoring is for planning and policymaking, early warning of natural resource emergencies, and managing nation-wide intervention programs. In addition to the vital statistics collected by lead sectors for the purposes of monitoring, information and data from other institutions could be complemented for analysis and decisionmaking.

It has been observed in several instances that by the time the results of data analysis reach the decisionmaker, the problem to be addressed by the monitoring system may no longer be a critical issue. To avoid such delays, institutions which have the capacity or at least have the structure to be strengthened for fast turnover of data, should be chosen for implementing the monitoring systems. To speed up the processing and analysis of information, experiences show that it is done most efficiently at the decentralized levels

such as a resource management domain rather than at a central office (Callahan, 1984). Similarly, institutional arrangement for relating the results of analysis to interventions should be identified at this stage. Without due consideration to this aspect, information will remain unused by decisionmakers. Proper identification of decision points would ensure a constant flow of information from monitoring systems to decisionmaking processes.

***Identifying indicators, conceptualization, and analytical methodology*:** Understanding the concepts associated with natural resource management and sustainability is essential for identifying variables on which information needs are to be generated. This is particularly useful in natural resource monitoring for planning and policymaking, and early warning. For example, analysis of programs and policies that may influence production patterns which depend on natural resources would require a different set of information than the ones that address improvements in the coping strategies of households affected by natural resource degradation and displaced through environmental migration (Unruh, 1993). However, given limited resources in implementing natural resource and sustainability monitoring systems, there is a need to identify appropriate indicators that truly and cost effectively reflect the status of natural resource and sustainability, and select appropriate factors that could be analyzed for designing interventions (Becker, 1997).

Sources and methods of data collection: Unfortunately, most natural resource and sustainability monitoring activities start with data collection without a clear definition of what data are needed and for what they are needed (D'Elia, 1995). Depending on the objective of natural resource and sustainability monitoring, the requirement of data would differ. The data sources that exists in a country should be identified before initiating any data collection activity. Generally, both primary and secondary sources of data are used for analysis and decisionmaking purposes in any type of monitoring system. In the past, much emphasis has been given to collect secondary data which were already available in several ministries to design intervention (Pickup and Smith, 1993). This was partly due to the poor infrastructure that existed in several developing countries, particularly in

sub-Saharan Africa and it was too expensive to collect primary data. While secondary data sources had been useful in providing an overview of natural resources problems, use of primary data played an important role in identifying specific solutions to these problems in several types of planning and policymaking efforts. The primary data could be collected either through quantitative or qualitative methods. Both quantitative and qualitative data could be gathered through natural resource and sustainability monitoring systems.

In identifying specific natural resource and sustainability problems, qualitative information may also be useful. On the other hand, information needed for planning and policymaking and for program management generally tend to be quantitative. The methods of data collection depend on the variables involved in data collection and the time involved in the process of planning and policymaking.

Converting natural resource and sustainability data into policy decisions: Conversion of data from primary and secondary sources into policy information is probably the most crucial stage in implementing natural resources and sustainability monitoring, since the very success of monitoring depends on the speed with which decisionmakers are informed with alternative intervention plans and strategies.

It should be recognized that in all types of monitoring systems, decisionmakers need information and not just data. Data processing and analysis transform data into policy information. With the advent of personal computers and their wide use in developing countries, the capability for data processing is generally better than the capacity for analysis. However, data processing is often confused with data analysis, and having some capacity to process data is seen as the capacity for data analysis. While data processing is a highly specialized technical skill, data analysis in natural resource and sustainability monitoring requires an understanding of the substantive issues in various fields such as forestry, fisheries, natural resource management, geographic information systems, remote sensing, planning, economics, sociology, policy analysis, and possibly other disciplines.

In the past, the types of data analysis included conceptualization of natural resource problems and identifying major causal factors; assessment of magnitude and trends of natural resource degradation; and classifying the nature and extent of the situation according to geographical location and socio-economic groups (Hassan and Hutchinson, 1992). While such analyses are useful as a starting point, they do not go beyond identifying various policy issues. There is an urgent need for providing information on various policy alternatives and their likely impact on the natural resource base and sustainability. Additionally, the indirect effects of intervention policies and programs need to identified and assessed (Lee et al., 1994). This would require an enhanced human capacity with advanced analytical skills which is a major limiting factor in designing and implementing policy interventions in several developing countries, particularly in the natural resource sector. At a resource management domain level, for example, the program managers need to be trained in understanding natural resource and sustainability issues along with the data analysis personnel. Increasingly, community participation in managing information and planning intervention is seen as an effective way of improving the sustainable use of natural resources. At all these levels, there is a need for multi-disciplinary training involving subject matter specialists such as social scientists, foresters, statisticians, agriculturalists, natural resource managers, and ecologists. National universities and research institutions within them and the natural resource assessment units in various sectoral ministries such as forestry, fisheries, wildlife and agriculture provide immediate opportunity to develop capacity in natural resource and sustainability monitoring.

Interpretation and transfer of policy information to decisionmakers: Equally important as the process of converting data into policy is the transfer of policy information into action plans. It is usually contended that the job of monitoring system ends when adequate information is generated and that it is not responsible for the quality of decisions made. While decisionmakers can not be forced to use information--since improving the sustainable use of natural resources is not the only objective in the decisionmakers' agenda--improved quality of information, method of presentation, and

provision of several alternatives to choose from help in better decisionmaking. It also helps if possible action plans are prepared for each type of policy alternatives that are being considered and their potential consequences are described clearly. National Environmental Action Plans that are currently prepared by several developing countries followed by the Earth Summit and their revisions provide opportunity for incorporating policy decisions generated with the support of natural resource and sustainability monitoring systems.

Review of the monitoring system: After implementing various stages described above, it is important to review the natural resource and sustainability monitoring system as a whole and at each stage for their intended contribution to the overall objective of monitoring. Such a review would help identify problems and the need for modifying monitoring strategies at different stages. Reallocation of resources could also be made according to the need to strengthen capacity at various stages of monitoring.

EMERGING ISSUES AND CHALLENGES IN NATURAL RESOURCE AND SUSTAINABILITY MONITORING[7]

Although natural resource and sustainability monitoring systems have been implemented under various names and approaches for the past decade in several developing countries, only a few countries could provide concrete examples of the use of information for effective policymaking and interventions to improve the sustainable use of natural resources (Lusigi, 1995; English et al., 1994). Even among those countries which have established an operational system for monitoring and evaluation of specific natural resource projects, several issues relating to the principles of natural resource and sustainability monitoring need to be redressed. Some of these emerging issues which are frequently suggested as being fundamental for successful implementation of natural resource and sustainability monitoring systems are presented in this section. Incorporating them by giving due consideration to their operational significance presents a challenge in developing comprehensive natural resource and sustainability monitoring systems.

Well-defined objectives for natural resource and sustainability monitoring: Information obtained through natural resource and sustainability monitoring could be used for planning, programming, and policymaking in a wide range of sectors including, agriculture, forestry, lands, fisheries, wildlife, economic planning, and finance. To meet these diverse information needs, five major objectives described in section two could be associated with natural resource and sustainability monitoring. While these objectives could operate at national, regional, and resource management domain levels, it is essential to explicitly identify the objective of the system to be designed since it is impossible to address all five objectives with one type of monitoring system. While natural resource and sustainability monitoring system should be designed with a specific objective, separate monitoring systems could be designed to meet each of these objectives within the same country. Once the objective of the monitoring system to be implemented is clear, the approach to develop the system should be tailored depending on the level of decisionmaking that is to be influenced. For example, a system that caters to the needs of regional resource planning would differ in its extent of coverage from a system designed for a resource management domain. Similarly, the research and impact assessment objectives of monitoring natural resources should be distinguished in designing monitoring systems (Campbell, et al., 1995).

Infrastructure for information generation and processing: One of the binding constraints in developing a comprehensive natural resource and sustainability monitoring system in developing countries has been the limited infrastructure to collect and process data from the field. In countries where there exists a well developed network of data collection systems, it is generally suggested that the existing infrastructure should be effectively utilized. However, in countries where there are no organized data collection systems, it may be necessary to create new infrastructure. Elsewhere, it is possible to combine the existing but poorly organized structures and reorient them towards specific goals of natural resource and sustainability monitoring (Hassan and Hutchinson, 1992).

In deciding whether to strengthen the existing infrastructure or to develop a new system of data collection, due consideration should be given to the sustainability and cost-effectiveness of the monitoring systems. It is essential to organize the system of data collection in such a way that it is operational with limited resources. Using the existing data collection infrastructure, provides an opportunity to reduce the cost of data collection. Since the personnel who have been conducting other field surveys could be trained easily in collecting data for natural resource and sustainability monitoring, the cost of training could be substantially reduced.

Similarly, for processing the data collected from the field surveys, it is also important to use the existing structure and strengthen them. This will substantially reduce the cost of human capacity building for data processing. However, in countries where data processing capacity does not exist, it is important to develop such capacity. To the extent possible, the data collection and processing activities in a monitoring system should be linked to the ongoing development activities. This would enable utilization of all possible means of data collection systems for improving the quality of information from the field. For example, the famine early warning systems that have been established to monitor food availability at the national level in several sub-Saharan African countries, provide an opportunity to build natural resource and sustainability monitoring systems. A typical example of this is the use of agricultural extension systems in countries, such as India, for monitoring the changes in the natural resource conditions (Misra, 1992).

Reducing time-gap in data processing, analysis and policy interventions: One of the major criticisms of the currently operating monitoring systems is that too much of data are collected while little is analyzed and much less is reported of what has been analyzed. The time gap between collection of data and analysis and analysis and reporting has been wide in the past that when information is given to decisionmakers, it becomes too late to make effective use of it. Experiences also show that lack of human capacity and resources for data processing, analysis and designing policies has become a major

impediment in generating timely information for interventions (Hassan and Hutchinson, 1992).

The nature of data analysis in monitoring systems in the past has also concentrated on compiling data from various sources and analyzing them at a single point which delayed the process of planning and designing policy interventions. To minimize this time lag, it is essential to decentralize data processing and analysis systems. In order to meet this task, attention should be paid to develop appropriate but flexible computer data processing systems at these levels. Also, issues relating to sophistication in data analysis and the time involved in several types of data analysis at various levels should be given due consideration. For example, simple mapping and geographical classification of natural resource bases would meet the needs of decisionmaking at the district level, while a detailed analysis of patterns of land use and other natural resource degradation may be necessary to design policies which will reverse the trends at the sectoral or national level.

Matching data analysis to decisionmaking needs: At all levels of decisionmaking--national, regional and resource management domain levels--data analysis should closely match the needs of decisionmakers and various alternative intervention scenarios should be presented to them. Lack of attention to this important issue has resulted in information from data analysis not being fully used in the decisionmaking process. This has also rendered several well-intended natural resource monitoring systems data-driven rather than user-driven (Falloux, 1989). One way to avoid the efforts of data collection and analysis becoming futile is to involve decisionmakers in the process of generation of information. This is best done by developing the monitoring system in continuous collaboration with decisionmakers through initial stages and frequently modifying the content of information generated to improve relevancy of information for their decisionmaking needs. It is generally suggested that a user survey be conducted to identify information needs before designing monitoring systems which should be followed by periodical workshops for decisionmakers to generate feed back on the usefulness of information in decisions related to natural resource problems faced at various levels. This will increase the user

participation in the monitoring system, enhance the local ownership, and reduce the probability of it becoming a process-driven system (D'Elia, 1995).

Information and action linkages: Once the data collected from the resource management domains have been converted into policy information, implementing these policies and programs is usually left to the decisionmakers. The political, cultural, and bureaucratic environment in which decisionmakers operate, tend to influence the speed with which decisions are converted into action. In addition, availability of timely information for making appropriate decisions and the quality of information presented to decisionmakers, play an important role in strengthening information-action linkages. It is also the responsibility of policy analysts to go beyond presenting information to help decisionmakers use the information to the fullest extent possible. One of the ways to achieve this is to provide decisionmakers with several policy alternatives that emanate from the information collected. Lack of capacity to convert information into decisions and decisions into action plans has been suggested as a crucial factor in implementing interventions. To increase the likelihood of the use of information in decisions and the timely implementation of intervention policies, it is important to organize workshops and other advocacy activities to sensitize decisionmakers towards understanding natural resource and sustainability issues and the importance of information-based decisions that improve sustainable use of natural resources.

Creating demand for information and making decisionmakers accountable: Lack of demand for natural resource and sustainability information obtained through monitoring systems from decisionmakers has been frequently suggested as a factor that diminishes the role of information in decisionmaking (Falloux, 1989). The assumption that the supply of relevant natural resource and sustainability information would create its own demand and result in effective decisionmaking towards intervention has been proven to be unrealistic by past experiences in natural resource monitoring. Thus, it is a responsibility of policy analysts to simultaneously find opportunities to create effective demand for their policy analysis output. The issue of creation of demand for natural resource and sustainability monitoring is closely associated with holding government

authorities and donor agencies accountable for the status and pattern of use of natural resources in a country. Unless this is done, provision of information and creating effective demand for such information will have very little impact on improving sustainable use of natural resources.

Nature and extent of decentralization: Decentralizing the process of data analysis, decisionmaking, and implementing interventions to assess natural resource degradation has been suggested as an improvement to the currently operating national level systems of natural resource monitoring. It is often suggested that natural resource and sustainability monitoring systems that are designed and operated by local communities could be more effective in implementing interventions and evaluating their benefits. While this is seen as most ideal, decentralization of the processes of information generation and decisionmaking has been slow in several developing countries. Decentralizing the process of information generation and use also has the advantage of reducing the time gap between problem identification and the necessary action. A decentralized decisionmaking process involves officials, for example, who implement interventions specific to a resource management domain. In decentralizing various activities of natural resource and sustainability monitoring, due consideration should be given to factors such as types of data collected, types of analysis to be conducted, existing capacity to process and analyze data, and the types of decisions that could be made since these affect the nature and extent of decentralization.

National focal point for information dissemination: While the natural resource and sustainability monitoring systems could be implemented by various sectoral ministries, such as forestry, fisheries, natural resources, to meet their own planning and policymaking objectives, it is important to have a focal office at the national level to have an overview of understanding the various systems operating in a country. Alternatively, one of the sectoral ministries could take the lead in documenting and disseminating natural resource information to relevant decisionmaking agencies. This helps in maintaining and providing an inventory of activities and in avoiding duplication of efforts among the sectoral ministries. More importantly, the natural resource and sustainability

monitoring focal office should play the role of "clearing house" for information related to natural resource and sustainability situation in a country.

Institutional and human capacity for natural resource and sustainability monitoring: For successful implementation of natural resource and sustainability monitoring systems, having a critical mass of people trained in natural resource issues and policy analysis from various sectors including the university and other academic institutions is a prerequisite. Lack of such capacity to translate data collected through monitoring systems to policy decisions and design interventions, poses a formidable challenge in several developing countries. Associated with this is the need for strengthening policy analysis capacity at decentralized levels. This would require reorientation of the approaches to capacity strengthening in natural resource management to meet specific requirements of localized decisionmaking.

Given the wide variations in the existing capacity to undertake natural resource and sustainability monitoring for planning and policy interventions among the developing countries, there exists an urgent need for strengthening the capabilities of training institutions in these countries to ensure long-term sustainability of capacity building efforts. This is better done through collaboration of institutions among developing countries in sharing information and facilities in capacity strengthening. Also, the right balance should be struck between investments in long-term post-graduate training and short-term in-service training efforts. One of the weakest areas in the process of translation of natural resource information into useful decisions is effective communication and presentation of information. The presentation of information must be user-specific and sensitive to the level of decisionmaking. This would enhance the use of information for intervention planning and appropriate decisionmaking at national, regional and village levels. However, this requires additional and specialized training in developing communication skills and should form an integral part of capacity strengthening initiatives in natural resource management (Babu, 1997).

Recognizing political economy issues, power structures and appropriate planning of institutions: Even with adequate capacity to implement natural resource and sustainability monitoring systems and to undertake natural resource planning policy analysis, no significant improvement could be made in upgrading natural resource and sustainability situations unless issues relating to political economy are recognized and addressed on a country-specific basis. It is also important to recognize the power structure and its influence towards policy reforms to make any headway in implementing natural resource management policies. It is not just enough to provide policy research reports from data analysis although it is a necessary factor in convincing the politically inclined power structures towards making appropriate decisions. Related to this is the placement of operational units responsible for natural resource policymaking appropriately within the government to achieve the objectives of utilizing the capacity in natural resource and sustainability monitoring more effectively. Lessons learned in the past decade in such attempts point to the variations in accomplishments in improving the sustainable use of natural resources due to this consideration (Hassan and Hutchinson, 1992).

Cost of natural resource and sustainability monitoring: An important but often neglected aspect of implementing natural resource and sustainability monitoring systems is the cost associated with operationalizing them (Pickup and Smith, 1993). In the past, information on the cost of implementation has not been documented adequately. Information on the investment and maintenance costs of monitoring systems is essential to evaluate the benefits of natural resource and sustainability monitoring against its costs. The monitoring system which is not cost effective may not be sustainable. The costs and benefits of natural resource and sustainability monitoring system as a planning and policy generating mechanism should be documented for comparison among countries.

GUIDELINES FOR EVALUATION OF MONITORING SYSTEMS AND RESEARCH NEEDS

Evaluation of natural resource and sustainability monitoring: The evaluation of natural resource and sustainability monitoring systems for their intended objectives is essential for reorienting them towards changing information needs and clients. Two types of evaluations are necessary: evaluating performance of the monitoring system for quality of information generated and meeting information needs; and evaluating the impact of information in influencing policy decisions.

Several criteria are used to evaluate the performance of monitoring systems. Timeliness of information in terms of quick turn-over of data for decisionmaking and periodicity of information generation is considered a good criterion. Other qualities such as decentralized use of information, user-driven nature, use of existing infrastructure, adequate capacity for analysis and interpretation of data, and continuous use of information from the monitoring systems for decisionmaking are also seen as equally important as the quality of information and decisions made by using it. Information from evaluation of monitoring systems for benefits in influencing policies may be useful as an instrument to gain resources and support for sustaining monitoring systems.

It is also important to compare the cost of information generation to the benefits attained in terms of changed policy impacts although it is generally agreed that such benefits are not readily quantifiable. One approach could be to document the use of information from the natural resource and sustainability monitoring systems for various planning and policymaking purposes on a case-by-case basis and estimate the costs saved in those analysis if the information were to be generated for each of these purposes in the absence of a comprehensive monitoring system. For example, a part of information collected by the monitoring systems could be used by donor agencies in their planning exercise which otherwise would involve additional donor resources for data collection. These benefits are in addition to the benefits of information for which the monitoring system is originally intended.

Natural resource and sustainability monitoring research: To enhance the effectiveness of natural resource and sustainability monitoring systems, it is important to provide the

planners, designers, and field staff with recent innovations in data collection, processing, analysis and interpretation, and decisionmaking. This could be done by observing the monitoring systems operated for various objectives and under different circumstances in other countries. Such learning process should be reinforced by additional research on the methods and practice of natural resource monitoring systems. Research is needed to develop new technologies of cost-effective data collection that would not compromise the quality and coverage of information. For example, comparing rapid rural appraisal methods and traditional resource surveys for their appropriateness under differing information needs would throw some light on minimizing the cost of data collection (Dorney and Leitner, 1985). Research is also needed in the choice of indicators which could reflect and predict the status of natural resources and their sustainable use with minimum cost and efforts involved in their collection (World Bank, 1995). Information technology and their appropriateness for compiling, processing, and analyzing data from the field should be studied in terms of their requirement for training and capacity strengthening. This includes computer hardware and software that are flexible and compatible for information exchange among various agencies in a country (Hassan and Hutchinson, 1992).

Research on the appropriate institutional structures for natural resource and sustainability monitoring would provide useful information for designing monitoring systems. Information on the success of bottom-up vs top-down approaches in information generation and decisionmaking should be analyzed under various circumstances. The use of information in the process of decisionmaking and the power structures that are involved should be understood on a country basis using case-studies. Additionally, political economy issues related to natural resource management interventions that emanate from natural resource and sustainability monitoring information should also be studied for their influence on policy implementation. Cost-effective methods of improving the quality of data collected, reducing the errors in compilation and processing should be identified. Training methods in developing skills for data processing, analysis, and interpretation at resource management domain, sectoral,

and national levels should also be researched for their effectiveness in generating adequate capacity in a shorter period of time.

CONCLUDING REMARKS

This paper presented an overview of concepts involved in natural resource and sustainability monitoring systems implemented in developing countries. Using the concept of resource management domains, it identified issues and challenges that need to be addressed by policymakers and planners in designing natural resource and sustainability monitoring systems. Efforts to develop monitoring systems, in the past, have had narrow focus on monitoring and impact evaluation of natural resource projects. Recent attempts to organize data collection systems at national and global levels continue to dwell on development and choice of indicators of natural resource monitoring. While this is an important area for further research, there is an urgent need for understanding the constraints and challenges that country governments face in using these indicators through a system of monitoring. There is also a need for reviewing existing natural resource monitoring systems on a case-by-case basis in order to understand their utility towards contributing to national and global databases. In this connection, it is important to bring the natural and biological scientists and planners and policy analysts together to develop consensus on information needs and on developing cost-effective monitoring systems.

Implementing monitoring systems for improving the natural resource base and its sustainability should be viewed as a dynamic process which should be modified as more information on the design and monitoring procedures are available. Inclusion or deletion of specific information to be generated through the monitoring system should be done on a continuous basis to meet the decisionmaking needs. A general principle of natural resource and sustainability monitoring valid for different objectives could be summarized as follows: a monitoring system which is simple, user-driven based on existing institutional structures which increases the capacity for analysis and interpretation and

has the commitment of relevant decisionmakers for using the information in planning and policy design is most likely to be sustainable and successful.

NOTES

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2. The sustainability and natural resource issues summarized in Table 1 were obtained from various sources which have identified emerging natural resource problems in developing countries. They include Schramm and Warford

(1989), Pearce et al. (1990), Munasinghe and Shearer (1995), Leonard, et al. (1989), Pearce and Warford (1993), Brouwer, et al. (1997), Goldman (1995), Carter and Howsam (1994), Naylor (1994), Pingali (1992), and World Bank (1996).

3. Only selective resource management domains and their issues are presented in the conceptual framework to identify the indicators that are to be monitored for changes in the nature and conditions of various resource components of a resource management domain. Similar issues and indicators for other resource management domains can be identified in natural resource and sustainability literature. See Munasinghe and Shearer (1995).

4. Much of the literature on natural resource monitoring dwells on the choice of indicators and measurement techniques for various natural resource problems (Bie, 1990). While it is important to develop appropriate and cost-effective indicators, their adoption and use are confined to locality-specific needs of resource managers within the countries. Unless, the existing infrastructure for establishing monitoring systems and incentives for information generation is well understood, identified indicators will be of limited use at the country level.

5. In spite of several advances made in developing global level resource monitoring systems such as Global Environmental Monitoring Systems and Global Resource Information Database, the country level efforts to develop and manage monitoring systems for natural resource management remains low and unorganized.

6. There is much to be learnt from the experiences in information generation and use in other disciplines such as agriculture and food and nutrition. For example, food scientists and nutritionists have increasingly interacted with policy scientists for the past two decades and have been able to penetrate into the decisionmaking systems of the governments and place food and nutrition at the top of the development agenda. See Quinn (1994). Unfortunately, similar efforts by natural scientists in placing natural resource issues in the policy and planning agenda have had only limited success.

7. The following sections borrow from institutional issues relating to food and nutrition information systems discussed in Babu and Pinstrup-Andersen (1994) which are also pertinent to designing natural resource and sustainability monitoring systems.

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Table 1—Sustainability and natural resource issues and problems by resource-management domains (RMD)

RMD	Land use	Water availability and use	Forest cover	Pasture cover	Soil quality	Biodiversity	Carrying capacity	Agrochemical use
Intensively irrigated agriculture system • Indus river basin • Indo-gangetic plains	Intensive use of land; declining productivity	Waterlogging; inefficient water use; poor drainage; water-born diseases	Declining forest areas due to increases in small-scale irrigation	Reduced land for pasture due to agricultural intensification	Salinization, waterrlogged soils; declining productivity	Reduced genetic diversity due to uniform crop varieties, resurgence and pesticide resistance	Pressure on land due to declining productivity	Drinking water contamination of nitrates and pesticides
Semi-arid lands • Sahel region • Semiarid tropical India • Northeastern Brazil	Land degradation; desertification; declining land productivity; cultivation of marginal lands	Drought conditions exacerbated by low and unpredictable rainfall	Deforestation for extensification of crop production; fuelwood shortage resulting in forest clearing	Destruction of vegetative cover, due to over-grazing	Overuse of soils, soil depletion, declining soil fertility	Loss of biodiversity resulting from destruction of vegetative cover	Population pressure; pushing cultivation into drier arid region	Intensified crop production increases the use of chemical fertilizers and pesticides
Hill-side slopes • Himalayan region • east Africa and central America	Declining land productivity	Downstream flooding; diminishing groundwater; highly variable rainfall	Destruction of forest cover; fuelwood shortage resulting in forest clearing	Reduction in vegetative cover due to expansion in land use for agriculture; over-grazing of common land	Soil erosion landsliding, gullying;	Decline in biodiversity due to forest clearing	Population pressure resulting in over-use of agricultural land	Increased agro-chemical use resulting in down-stream water contamination
Forest margins • Amazonia • Sub-Saharan Africa	Large-scale deforestation; declining land productivity	Increased water runoff resulting in flooding; poor drainage	Fuelwood collection, availability and use; loss of forest-based production	Degradation of pasture land due to overgrazing	Decline in soil fertility; increased soil erosion; soil degradation	Threat to biodiversity due to destruction of forests; decline in natural habitats	Population pressure due to expansion of agriculture	Intensification of small-scale farming resulting in increased use of chemical fertilizers rather than organic fertilizers
Wildlife/buffer zones • Eastern and Southern Africa	Competing land use between wildlife and agriculture	Increased water runoff due to clearing of vegetation	Depletion of forest cover in buffer zones	Conversion of natural pastures into farming lands	Reduced soil fertility due to continued agricultural production	Reduced biodiversity due to reduction in forest areas	Increased pressure on land from wild animals and humans	Potential for water contamination due to chemical fertilizer runoff from agriculture
Fragile ecosystems, eg: Mangrove forests • Madagascar • Honduras	Competing land use resulting in reduction of natural mangroves	Water quality deterioration	Destruction of mangrove forests; disappearance of seasonal lagoons	--	--	Depletion of fish stock; destruction of other inhabitants in the fragile ecosystems	Population pressure and increased commercialization results in land use conflicts	Agrochemical pollution from crop production systems
Desert margins • Egypt • Sudan • Botswana	Land degradation	Water runoff; low and erratic rainfall	Bush encroachment; excess fuelwood demand	Reduction in vegetative cover	Soil erosion due to wind; reduction in soil organic matter	Biological degradation	Excessive number of animals; overstocking; human population	--

Table 1 (Contd)

RMD	Land use	Water availability and use	Forest cover	Pasture cover	Soil quality	Biodiversity	Carrying capacity	Agrochemical use
Community watersheds • Java • Haiti • India	Expansion of permanent cultivation in upper watershed areas	Changed water flows; flooding in low lands; low water quality	Large-scale deforestation and encroachment into upper watershed areas	Reduced pasture cover due to increase in agricultural land use	Soil erosion, increased sedimentation	Decreased fish in streams and coastal areas	Increasing population density of farmers and fishermen	Use of chemicals in upland; enter into water streams of low lands
Inland lake/fish production systems • Bangladesh • Malawi	Land pressure due to competing uses	Reduction in the quality of water	Removal of trees and shrubs for aquaculture	Competing use of ponds and land; little land for pasture	Sedimentation from soil erosion - natural siltation	Overexploitation of specific species; destruction of fish habitat	Man-made stresses reduce resilience of the fisheries	Discharges of agro-chemicals from crop lands
Range lands/ grazing systems, pasture lands • Amazon • Central America	Increasing cereal cultivation	Periodic and cyclic droughts	Reduced forest cover due to fodder cultivation	Loss of vegetative cover	Low soil fertility, soil erosion in slopes; soil compaction	Decreases with severe disturbances	Reduced productivity and overcapacity due to population pressure	Chemical fertilizer use resulting in low water quality

Figure 1--A conceptual framework for designing natural resource and sustainability monitoring system [3]

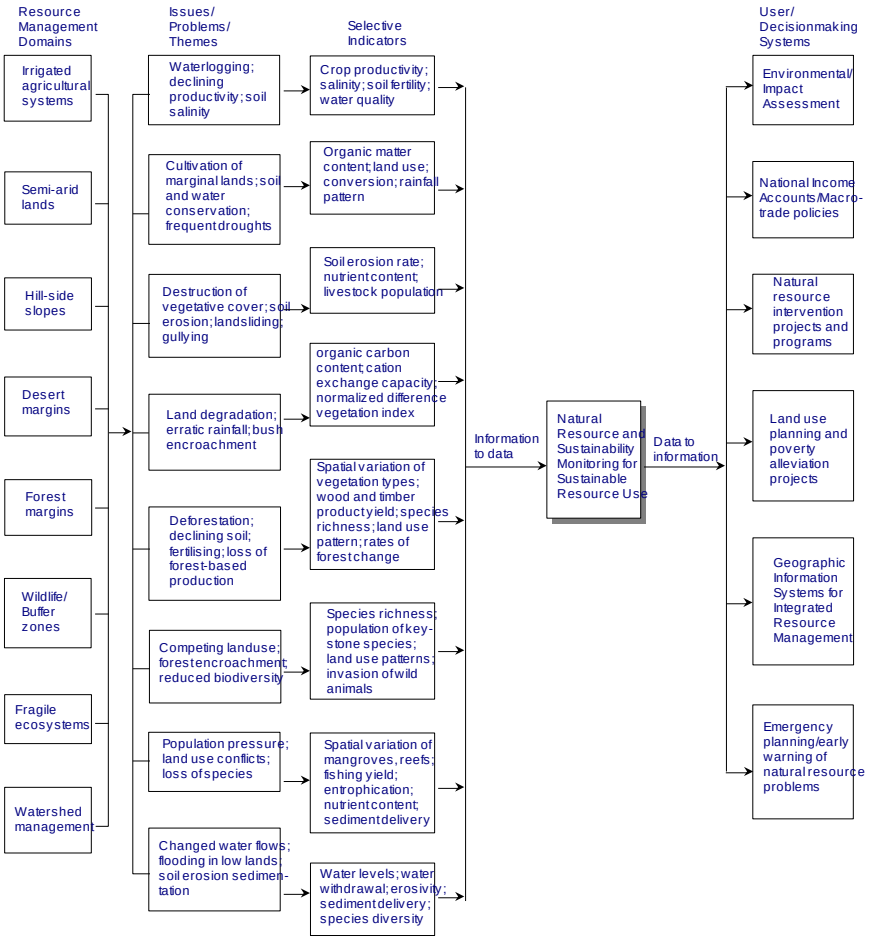


Figure 2--Types and objectives of natural resource and sustainability monitoring systems

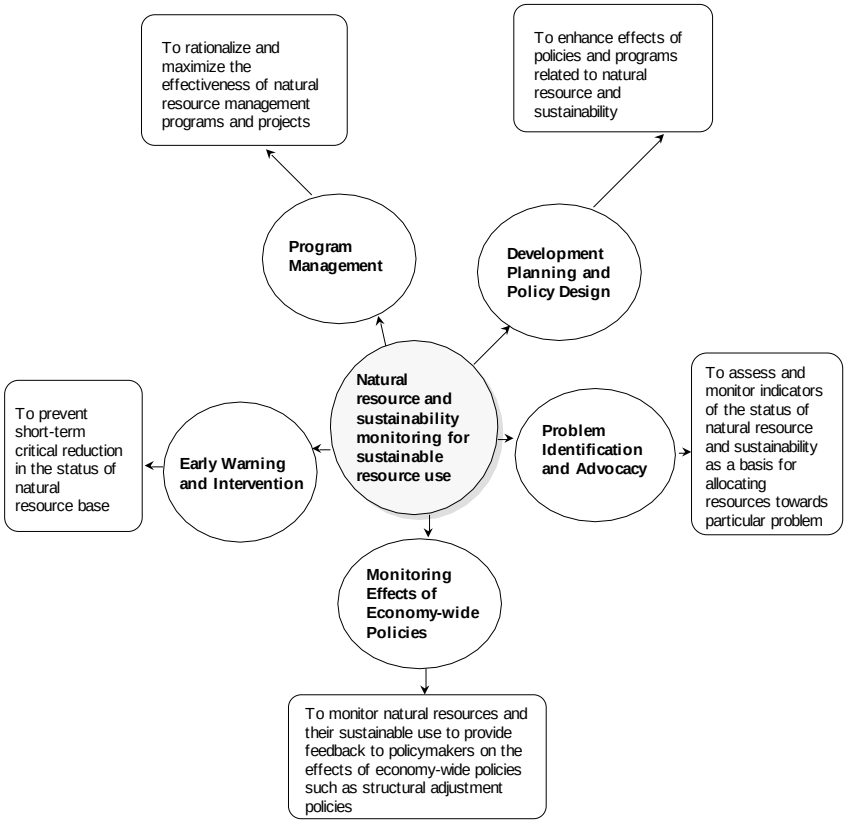
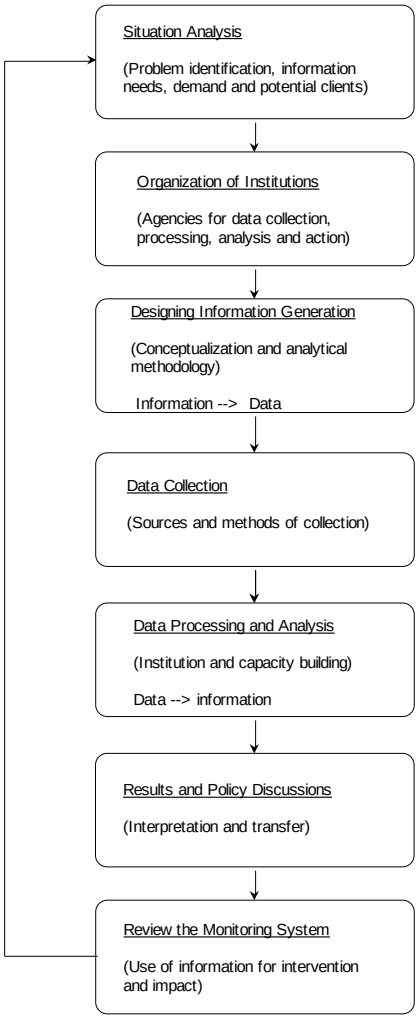
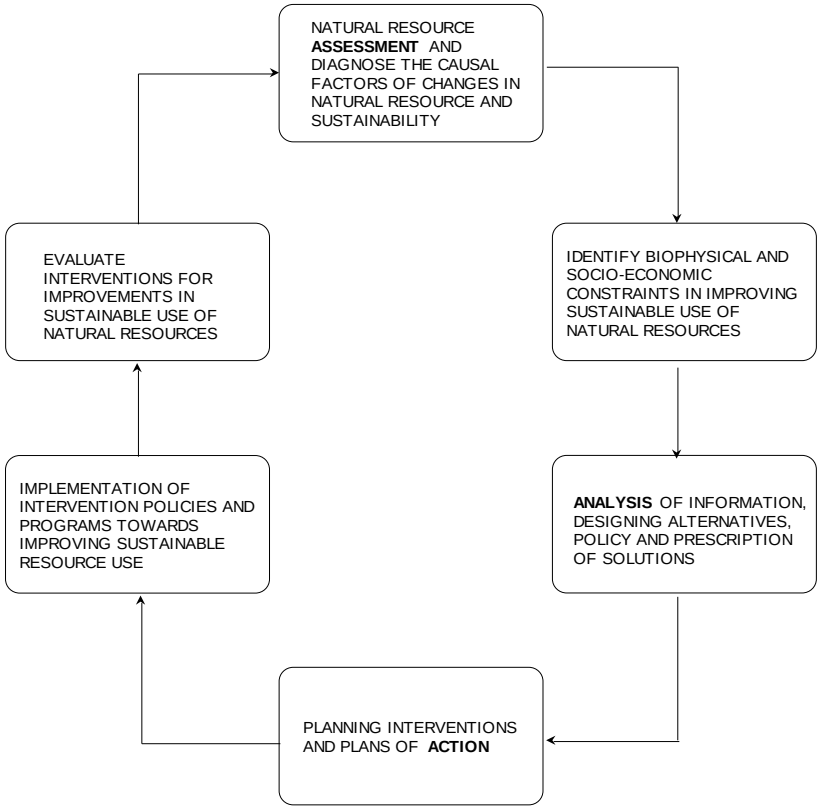


Figure 3--General methodology of natural resource and sustainability monitoring



Adapted from Babu and Pinstrup-Andersen (1994)

Figure 4--Stages of implementing natural resource and sustainability monitoring



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