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Ecosystem-Based Management of Natural Resources:

a Step Towards Sustainable Development

Prof. Rodolphe Schlaepfer

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a Step Towards Sustainable Development

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Foreword

As we can read from Risto Seppälä in the IUFRO News Vol. 25, 1996, issue 3, the scientific community has become increasingly interested in sustainability, and IUFRO, to demonstrate this has established a special Task Force on sustainable Management.

The following paper is an attempt to give an overview of the recent developments mainly in North America, in the field of sustainable and ecosystem-based management of natural resources, including forest resources. The subject is in line with the actual preoccupation of IUFRO and should be of interest to all division.

Acknowledgments

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Contents

Abstract

Some international efforts, including the Earth Summit of Rio in 1992, as well as the notions of sustainability and ecosystem are briefly introduced. The concept of ecosystem management developed recently in the United States is discussed. Principles of managing natural resources for sustainable development are presented. A definition of ecosystem-based management is proposed. Instruments and scientific challenges are identified. A series of questions which should be answered for the implementation of ecosystem-based management are presented.

1. Introduction

The idea of using an ecosystem approach in managing natural resources is not new. In the preface of his remarkable book **The Ecosystem Concept in Natural Resource Management** Van Dyne (1969) wrote: "This volume will be timely because of the widespread interest in ecosystem approaches". The book is based on a symposium held at the annual meeting of the American Society of Range Management in Albuquerque, New Mexico, on February 12-15, 1968.

Since then, progress has been realized. However, the world's awareness of the emerging problems due to different pressures on the ecosystems on which our society depend for its well being has increased considerably. It has also become clearer, that plants, animals, microorganisms, soils, air, and water constitute a natural heritage of social, economic, ecological, and intrinsic value that needs to be preserved, where possible enhanced, and handed on to future generations.The need to improve the protection and management of ecosystems in a way that balances and integrates environmental and development questions, is now recognized as an important challenge for sustainable development. This new awareness has led to a series of international and national efforts aimed at assuring the quality of life to both present and future generations.

An objective of this paper is to review ideas on how natural resources can be managed for sustainable development. A second objective is to provide a general conceptual framework within which the research and the teaching of the new professorship in Ecosystem Management in the Department of Rural Engineering, Swiss Federal Institute of Technology, Lausanne, can be defined. Although the paper was developed during a sabbatical leave at Oregon State University in Corvallis, USA and is therefore essentially inspired by North American work for forest ecosystems, the described ideas are applicable for other natural resources and in different ecoregions.

2. Background and recent developments

2.1 International efforts

Five documents resulted from the Earth Summit held in Rio in 1992.

- The **Rio Declaration on Environment and Development** includes 27 principles defining the right and the responsibilities of nations as they pursue human development and well being. The following principles are especially important for management as well as for research:

  - People are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature (Principle 1).

  - The right to development must be fulfilled so as to equitably meet development and environmental needs of present and future generations (Principle 3).

  - In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it (Principle 4).

  - States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem (Principle 7).

  - States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowlege, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies (Principle 9).

  - In order to protect the environment, the precautionary approach shall be widely applied by the States according to their capabilities (Principle 15).

  - Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority (Principle 17).

- **Agenda 21** reflects a global consensus and commitment at the highest political level on how to make development socially, economically, and environmentally sustainable. Among other options it includes protecting the atmosphere, an integrated approach to planning for and managing land resources, combatting deforestation, managing fragile ecosystems: combatting desertification and drought and sustainable mountain development, promoting sustainable agriculture and rural development, conservation of biological diversity, managing biotechnology, protecting and managing the oceans, protecting and managing fresh waters, and supporting science for sustainable development.

- A non-legally-binding, authoritative **Statement of Forest Principles** to guide managing, conserving, and sustainably developing all types of forests, which are essential to economic development and maintaining of all forms of life.

- The **United Nations Framework Convention on Climate Change** aim is to stabilize greenhouse gases in the atmosphere at concentrations that will not dangerously upset the global climate system.

- The **Convention on Biological Diversity** was signed by more than 150 governments at the Rio "Earth Summit" in 1992. It became effective on 29 December 1993 and has become the centre-piece of international efforts to conserve the planet's biological diversity, ensure the sustainable use of its components, and promote the fair and equitable sharing of the benefits arising from use of genetic resources.

The Ministerial Conference on the Protection of Forests in Europe, held in Helsinki in 1993, is a follow-up of the Rio Summit**.** The Conference agreed on two general guidelines and two resolutions for specific actions.The **General Guidelines for the Sustainable Management of Forests in Europe** in which the sustainable management of forests is defined.The **General Guidelines for the Conservation of the Biodiversity of European Forests** recognizes conservation and appropriate enhancement of biodiversity as essential parts of sustainable forestry. The **Resolution for Forestry Cooperation with Countries with Economies in Transition** defines principles for the collaboration with the eastern European Countries. Finally, the **Resolution for Strategies for a Process of Long-term Adaptation of Forests in Europe to Climate Change** reflects the European consensus on how to manage the forests in view of potential climate change.

The Montreal Process and the Helsinki Process are two different and highly visible international series of efforts to implement the UNCED Forest Principles, the Agenda 21, the Convention on Biodiversity, and the Helsinki Resolutions. The first was initiated in Montreal and the second in Helsinki. They defined criteria and indicators for evaluating and measuring the sustainable development of forests. Both processes recognized the importance of biodiversity as a criterion for sustainably managing the forests.

The objective of the International Geosphere Biosphere Program (IGBP) is to describe and understand the interactive physical, chemical, and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occuring in this system, and the manner in which they are influenced by human activities. IGBP has eight core projects, including, among them, Global Change and Terrestrial Ecosystems (GCTE), Past Global Changes (PAGES), and Land Use/Cover Change (LUCC).

At the last World Congress of the **International Union of Forest Research Organizations (IUFRO)** in Tampere, Finland, in 1995, sustainability was obviously considered an important field of investigation for forest researchers and led, <u>inter</u> <u>alia</u>, to the establishment of a IURO Task Force on Sustainable Forest Management by IUFRO, ExecutiveBoad.

These examples are all important for defining how to manage natural resources based on sustainable development and how to identify research priorities that will allow science to stay ahead of the game. The fact that different political, socioeconomic, and geographically diverse countries apparently agree on the importance of issues such as biodiversity is significant.

2.2 Sustainability, its potential and its limitations

Sustainability is an old notion, used as a goal in forestry for more than 100 years to manage forests for timber production, as well as in fisheries and wildlife management. However, now the concept is used more generally. According to Stankey (1995), **sustainability** is fundamentally a sociopolitical construct rather than a scientific concept capable of precise, unequivocal measurements. It reflects a state to which we aspire, it embodies a concern with our ability to exist as a species, and it opens the door for scientists and technical specialists to engage society in an issue of mutual concern.

Leopold in "A Sand County Almanac", first published in 1949 and now an environmental classic, uses the term **sustained carrying capacity** to describe the state of land and biotas.

In the Rio Declaration on Environment and Development, **sustainability** is defined as the **equitable meeting of development and environmental needs of present and future generations.**

That foresters made important attempts to define sustainability after the Rio Summit is not surprising. Forests represent 27% of the land-cover of the Earth.

The Helsinki Conference defined **"sustainable management of forests" as** the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfill, now and in the future, relevant ecological, economic, and social functions, at local, national, and global scales, and that does not cause damage to other ecosystems (Ministerial Conference 1993).

In the United States, in January 1992, a national conference entitled **Defining Sustainable Forestry** was held. Its purpose was to begin developing a common framework on which to base the future development of forestry; the conventional approaches that have defined forestry for the past century were to be replaced by an ecosystem approach that will guide it into the next century. At the conference, no single theme has been better developed than the idea that **sustainable forestry must be ecologically sound, economically viable, and socially desirable** (Aplet *et al.* 1993).

For Bormann *et al.* (1994b), **ecosystem sustainability** is the degree of overlap between what people collectively want - reflecting social values and economic concerns - and what is ecologically possible in the long term. The overlap is dynamic because both societal and ecological capacity continually change. They advocate that the desires of future generations be protected by maintaining options for unexpected future ecosystem goods, services, and states. In their very interesting paper, they also proposed the Pinchot Standard and the Pinchot Efficiency for assessing the condition and performance of the ecosystem relative to the demands made on it. The Pinchot Standard is based on the ecological properties that must be sustained for a given set of goods, services, and states which should be produced by the ecosystem and on what is actually sustained. The Pinchot Efficiency includes also the target values and the actually obtained values of the desired goods, services, and states. The approach presented by these authors to calculate sustainability deserves to be tested in practical situations.

When the need to define sustainable forestry with **criteria and measurable indicators** became obvious, international, national, and private initiatives delivered different proposals for what could be used. One example is the issue of **forest certification**, which is defined by Elliott and Hackman (1996) as a voluntary process that results in a written certificate being produced by an independent third party attesting to the location and management status of the forest from where the forest product originated. Certification involves independent assessment of a forest management operation on the ground using specified social, ecological, and economic criteria or standards. Other examples are the criteria adopted by the Montreal and the Helsinki Processes.

An important result of **the Montreal Process** is the list of **criteria for conserving and sustainably managing temperate and boreal forests** (Montreal Process 1995), including conserving of **biological diversity,** maintaining **productive capacity** of forest ecosystems, maintaining forest ecosystem **health and vitality,** conserving and maintaining **soil and water resources,** maintaining forest contribution to **global carbon cycle,** maintaining and enhancing long-term **multiple socio-economic** benefits to meet the needs of societies, and creating legal, institutional and economic frameworks for forest conservation and sustainable management.

The European criteria for sustainable forest management adopted by the first expert follow-up meeting of the Helsinki Conference in 1994 are: maintaining and appropriately enhancing **forest resources** and their contribution to **global carbon cycles**, maintaining forest ecosystem **health and vitality,** maintaining and encouraging **productive functions** of forests (wood and non-wood), maintaining, conserving and appropriately enhancing **biological diversity** in forests ecosystems, maintaining and appropriately enhancing **protective functions** in forest management (notably soil and water),and maintaining other **socio-economic functions** and conditions.

Despite these international definitions, the practical application of criteria and indicators in management and policy is still distant. As Brooks (1996) pointed out recently, "although it required a considerable effort to define the criteria and select the preliminary list of indicators, no consensus has been reached on how individual indicators should be interpreted". The reasons may be found in the **important limitations** of the notion of sustainability and the unanswered **open questions** that follow:

- One problem is the difficulty of defining the **spatial and temporal scale** at which sustainability should be attained. Should we manage our natural resources to be sustainable at the site level, regionally, nationally, internationally or even globally? Should we work towards sustainability at the short-, mid- or long-term horizon? Most publications avoid these delicate questions.

- Another question is **"What should be sustained?"**. What "sustainable use of a resource" means, is not always clear. This can be the case when different and simultaneous uses are conflicting in the same ecosystem, for example, timber harvesting and habitat improvement for endangered species, or when two adjacent ecosystems are strongly interacting, when ecosystems are too small, or when they have an unfavorable patch configuration. Because of the multiple, and often contradictory, objectives of sustainability, finding the optimal solution is a complex process. For the resource manager, acting alone, finding the optimal solution is often impossible. Participation of all stakeholders in formulating management objectives can facilitate the process.

- A third obstacle is the **scarcity of scientific knowledge** on many issues of sustainability. An impressive body of scientific results exists about individual elements and processes of ecosystems at the site scale, but not enough is known about many long-term effects or interactions at the landscape scale. Examples are the long-term interactions between wildlife and human interventions and the long-term ecological and economic effects of nitrogen deposition on the productivity and health of ecosystems.

- The last and most difficult question is **"How should we understand sustainability, given the increasing world population?".** Kauppi (1995) documented the obvious contradiction between the idea of sustainability and the population growth of the Earth. The problem of growing population can exist regionally, as it has in California for example.

These limitations should not be an excuse to reject sustainable management as an ideal, however. Progress can be made by little steps, based on the best available information and by always having in view the quality of life for future generations.

2.3 The notion of ecosystem

When natural resources are being managed, ecosystems are necessarily being manipulated. The concept of ecosystem is therefore essential in the context of sustainable use of natural resources.

"Ecosystem" has been variously defined. A relatively simple definition is "Ecosystem is a dynamic complex of plant, animal, fungal, and micro-organism communities and their associated non-living environment interacting as an ecological unit" (Heywood and Watson 1995). Or "An ecosystem is an area (or volume) where species interact with the physical environment, and a community is the assemblage of interacting species in an ecosystem" (Forman 1995). A more sophisticated but more explicit definition is given by Odum (cited in Kimmins 1987): "Any unit that includes all of the organisms (i.e., the community) in a given area interacting with the physical environment so that a flow of energy leads to a clearly defined trophic structure, biotic diversity, and a material cycle (i.e., exchange of materials between living and non-living parts within the system) is an ecological system or an ecosystem".

Ecosystems are characterized through their composition, structure, processes (the transformation of energy and matter within the ecosystem), flows, interactions between their elements, successional stage, spatial configuration, disturbance processes like fire, flood, drought or windthrow, and their functions.

Functions are largely defined in human benefit terms: goods, services, and states. Examples of ecosystem functions are production of harvestable products (such as timber, fish, game, medicinal plants), water supply, soil quality, habitat for wildlife, flood control, erosion control, recreation, visual quality, cultural value, and carbon sink. Ecosystems also interact with their environment, including adjoining ecosystems.

The term ecosystem is used in many ways.

The Earth's ecosystem. In the Rio Declaration on Environment and Development, Principle 7 says that "States shall cooperate in a spirit of global partnership to conserve and restore the health and integrity of the Earth's ecosystem".

Agenda 21 from the 1992 Earth Summit contains the following examples:

Ecosystems as components of land. Agenda 21, chapter 10, says that land is normally defined as a physical entity in terms of its topography and spatial nature; a broader, integrative view also includes natural resources: the soils, minerals, water, and biota. These components can be conceptually organized into ecosystems that provide a variety of services essential to maintaining the integrity of life-support systems and the productive capacity of the environment. Land is a finite resource, but the natural resources it supports can vary over time and according to management conditions and uses. Leopold (1949), when presenting his concept of the land ethic, already had a broad view on land: "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts . . .. The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land".

Forest ecosystems. Agenda 21, chapter 11, is concerned with management-related activity to enhance the protection, sustainable management, and conservation of all forests. It supports ensuring the sustainable management of all forest ecosystems and woodlands, through improved planning, management, and timely implementation of silvicultural operations, including inventory and relevant research, as well as rehabilitating degraded natural forests to restore productivity and environmental contributions, giving particular attention to human needs for economic and ecological services, wood-based energy, agroforestry, non-timber forest products and services, watershed and soil protection, wildlife management, and forest genetic resources.

Buffer and transition zones. Agenda 21, chapter 11, calls for management-related activity undertaking and promoting buffer and transition zone management.

Fragile ecosystems. Agenda 21, chapter 12, recognizes that some especially fragile ecosystems, with unique features and resources, are important to protect. Fragile ecosystems include deserts, semi-arid lands, mountains, wetlands, small islands, and certain coastal areas.

Mountain ecosystems. Agenda 21, chapter 13, considers that mountain environments, as major ecosystems representing the complex and interrelated ecology of our planet, are essential to the survival of the global ecosystem. Management-related activity includes integrating all forest, rangeland, and wildlife activities in such a way that specific mountain ecoystems are maintained.

Natural ecosystems. Agenda 21, chapter 15, notes that the natural ecosystems of **forests, savannahs, pastures and rangelands, deserts, tundras, rivers, lakes, and seas** contain most of the Earth's biodiversity, and proposes that long-term research be undertaken on the importance of biodiversity for the functioning of ecosystems and the role of ecosystems in producing goods, environmental services, and other values supporting sustainable development.

Aquatic ecosystems. Agenda 21, chapter 18, contains objectives for the protection of water resources, water quality, and aquatic ecosystems and proposes to adopt an integrated approach to environmentally sustainable management of water resources, including the protection of aquatic ecosystems and freshwater living resources.

Coastal ecosystems. Agenda 21, chapter 18, also recommends to put in place strategies for the environmentally sound management of freshwater and related coastal ecosystems, including consideration of fisheries, aquaculture, animal grazing, agricultural activities and biodiversity.

These examples show that the term ecosytem can be used not only in connection with **different types of land-use and land-cover, but also at a variety of spatial scales**. As pointed out by Salwasser *et al.* (1993), "All ecosystems are parts of larger ecosystems that receive their "externalities" and, in turn, set the context for conditions in the subsystems". The ultimate ecosystem is the Earth's biosphere. Unless otherwise described, I use "ecosystems" or "local ecosystems" to refer to patches, corridors, or area of matrix within a landscape.

Four other ecosystemic concepts play an important role in management: **edges, borders, boundary zones and ecotones**. Forman (1995) uses them as follows:

> Each landscape element contains an edge, the outer area exhibiting the edge effect, i.e. dominated by species found only or predominantly near the border. The inner area of a landscape element is considered the interior or core and is dominated by species that only or predominantly live away from the border. A border is the line separating the edges of adjacent landscape elements. The two edges combined compose the boundary or boundary zone. When species distributions within the boundary zone change progressively or evenly from side to side, analogous to a compressed gradient, this describes an ecotone.

An ecotone is the transition zone between two ecosystems. It usually has some characteristics of the two ecosystems, but also has an ecological structure of its own. Examples of ecotones are alpine timberlines, forest-grassland transition zones, and riparian areas. Ecotones play an important role for biodiversity as well as for landscape esthetics. Research about the dynamic of ecotones in space and in time and about managing ecotones is becoming challenging and important (Navey and Lieberman 1994).

The Rio Summit, and other international and national initiatives show that people generally agree about the need to manage natural resources with a view to sustainable development. The documents cited in this chapter and other publications help identify the characteristics of such management.

2.4 Ecosystem management

2.4.1 Introduction

To apply ecological principles in management, a variety of approaches has been proposed. Examples are sustainable forestry, new forestry, multiple-use forestry, adaptive management, structure-based management, and ecosystem management . In this chapter, I will describe ecosystem management, developed recently in the United States.

2.4.2 The definition of ecosystem management (EM)

Different definitions for ecosystem management were recently listed by Baker *et al.* (1995). Some examples are:

- Gordon (1993) gave an excellent idiosyncratic overview of ecosystem management**.** It is, he says, at minimum, people trying to accomplish something in a bounded space. He considers ecosystem management as a tool to achieve sustainability which differs from multiple-use management in focusing on inputs, interactions, and processes, as well as on uses and outputs.

- Grumbine (1994) said "ecosystem management is integrating scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term".

- The Ecological Society of America (Christenson *et al.* 1996) said :

  Ecosystem management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function. Ecosystem management includes sustainability, goals, sound ecological models and understanding, complexity and connectedness, the dynamic character of ecosystems, context and scale, humans as ecosystem components, adaptability, and accountability.

- Wood (1994) stated "ecosystem management is integration of ecological, economic, and social principles to manage biological and physical systems in a manner that safeguards the ecological sustainability, natural diversity, and productivity of the landscape".

- The Interagency Ecosystem Management Task Force (1994) established by the Clinton Administration gave this definition:

  Ecosystem management is a goal-driven approach to restoring and sustaining healthy ecosystems and their functions and values using the best science available. It entails working collaboratively with state, tribal and local governments, community groups, private landowners, and other interested parties to develop a vision of desired future ecosystem conditions. This vision integrates ecological, economic, and social factors affecting the management unit defined by ecological, not political boundaries. The goal is to restore and maintain the health of ecosystems while supporting economies and communities.

- The definition used by the USDA Forest Service is:

  Ecosystem management is a concept of natural resources management wherein national forest activities are considered within the context of economic, ecological, and social interactions within a defined area or region over both short and long-term (Thomas and Huke 1996).

These last three definitions, as opposed to the others given here, explicitly relate ecosystem management to the integration of ecological, economic, and social factors.

Ecosystem management is clearly a complex and interdisciplinary type of management that needs good monitoring and relevant scientific contributions. Also, people clearly are fundamental elements of ecosystem management.

2.4.3 The political background of ecosystem management in the Pacific Northwest

During the last decade, as a result of the discussions about the style of management used before 1990 on public lands - clearcut and short rotation-, considerable effort was put into ecosystem management and ecosystem management research in the Pacific Northwest.

This constellation was summarized by Baker *et al* .1995:

> By 1993, a series of court orders had brought timber harvesting on federal lands to a virtual half within the range of the northern spotted owl (in western Oregon and Washington and northern California). Federal courts ruled that the U.S. Forest Service (USFS) and Bureau of Land Management (BLM) had failed to produce plans satisfying the requirements of several laws, including the National Forest Management Act of 1976, the Endangered Species Act of 1979, and the National Environmental Policy Act of 1969 (FEMAT 1993). Regulations issued for the USFS under the National Forest Management Act require that "fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" and require provision "for diversity of plant and animal communities and tree

species". The Endangered Species Act protects all species formally listed as endangered or threatened.

Legal battles focused initially on the northern spotted owl, listed as threatened by the U.S. Fish and Wildlife Service. Northern spotted owls are closely associated with habitat found most often in old-growth forests, that is, forest stands where many old, large trees remain in the overstory. Gradually, the debate shifted from dealing with one species, the northern spotted owl, to considering all species associated with old-growth forests in the Pacific Northwest.

Historically, timber harvests from federal lands accounted for about one-third of total timber sales in western Oregon and Washington and northern California (FEMAT, 1993). Loss of these timber harvests resulted in severe economic disruption, particularly in small communities heavily dependent on timber from federal land for jobs. In response to this problem, President Clinton convened a day-long conference on 2 April 1993 in Portland, Oregon. He posed the following question, "How can we achieve a balanced and comprehensive policy that recognizes the importance of the forests and timber to the economy and jobs in this region, and how can we preserve our precious old-growth forests, which are part of our national heritage and, once destroyed, can never be replaced?

Following the conference, President Clinton created three interagency working groups:the Forest Ecosystem Management Assessement Team (FEMAT), the Labor and Community Assessment Team, and the Agency Coordination Team. The FEMAT report was published in July 1993 (FEMAT 1993). The interagency working groups established by President Clinton represent the start of ecosystem management in the Pacific Northwest.

2.4.4 The controversies about ecosystem management

Although ecosystem management is generally recognized as a good conceptual basis for sustainable development, it is also a subject of controversy. Some people support it vigorously, others reject it categorically. As Bennett (1966) said,

> while many concepts and values are common to most views of ecosystem management, major differences also exist. Some ecosystem management advocates focus almost exclusively on ecological considerations. Others see ecosystem management as a way to reconcile human needs for wood products with environmental values.

In the United States, the main causes of this phenomenon are to be found in the reactions to the process behind the President's Forest Plan for the Pacific Northwest, as well as to the adopted solution, which corresponds to a drastic diminution of harvested wood volume. The following citations are examples of skeptical voices:

> The FEMAT was led by experts who had previously advocated and authored plans that favoured the natural reserve approach to managing forests for biodiversity, old-growth-dependent species (e.g., the northern spotted owl), and other values. There were no scientists on the team who represented landscape management (Hampton 1994).
>
> The FEMAT report ignores large and tangible economic losses or masks them by claiming dubious economic benefits (McKillop 1994).
>
> Efforts to operationalize the ecosystem idea by making ecosystem protection the basis of land use management and natural resource policy are awash in confusion and pseudoscientific buzzwords because they gloss over the concept's inherent characteristics of spatial and temporal vagueness (Fitzsimmons 1996).

Cortner *et al*. (1966) noted that:

> There is little consensus about the new terminology, conceptual categories, and classifications used to discuss ecosystem management. Because of this diversity, it is important that we look at all aspects of ecosystem management to determine the full range of its possibilities and limitations.

Because of these views we should ask the question "What can be improved?".

2.5 The scientific contributions

Science is certainly one of the driving forces in the shift to ecosystem-based management from a mainly commodity production oriented forestry. The scientific contributions are numerous and diverse. In **traditional forest sciences**, much research has been conducted in silviculture, tree genetics, insect and disease control, harvesting, engineering, and forest management, often with the goal to maximize and sustain wood production. **Ecology**, by improving our knowledge about the interactions between plants, animals, and their physical environment has contributed to a better understanding of the functioning of forest ecosystems and of the consequences of natural and human pressures. The methods and results of the emerging science of **landscape ecology** have many applications in forestry, especially the knowledge gained about the relationships among the building blocks of the landscape, and the functioning of the landscape as a system. **Conservation biology** differs from traditional resource conservation in being motivated not by utilitarian, single-species issues, but by the need for conservation of entire systems and all their biological components and processes (Meffe and Carroll 1994). Its biology has roots in individual disciplines. Its conservation, based on the island biogeography theory, is the fundament of preserve systems and national parks. **Ecosystem dynamics**, with disturbance and landscape-change oriented scientists, focus on causes and effects of changing landscape patterns. Information on the historical variability of ecosystem conditions and the natural disturbance regime that influence such variability is increasingly used in design of ecosystem management systems (Swanson *et al.* 1993). Assessment of management effects is approached in part in terms of alternation of disturbance regimes from the "natural" to "managed" periods. Landscape management design elements include areas with differing frequency and severity of treatments based on natural disturbance regimes.

The science community is not only aware of the valuable contribution of research but also of the many questions and unsolved problems in managing natural resources. Intensive research on these problems is going on all over the world. In the Pacific Northwest, there are many organizations involved and many ongoing programs and projects that could provide inspiration for other parts of the world. I will mention only three programs and three publications, a small sample.

Long-Term Ecological Research at the H.J. Andrews Experimental Forest (LTER4). With an initial set of six sites selected in 1980, the National Science Foundation established the Long-Term Ecological Research (LTER) Program to conduct research on long-term ecological phenomena in the United States. The present total of 18 sites represents a broad array of ecosystems and research emphases. The LTER Network is a collaborative effort among over 600 scientists and students which extends the opportunies and capabilities of the indiviual sites to promote synthesis and comparative research across sites and across ecosystems. The H.J. Andrews Forest in Blue River, Oregon, is one of the 18 sites of the network. The central question guiding its studies is: "How do land use, natural disturbances, and climate change affect three key ecosystem properties: carbon dynamics, biodiversity, and hydrology?"

Coastal Oregon Productivity Enhancement Program (COPE). COPE, initiated in 1987, is another impressive contribution of science. It is a cooperative effort among the College of Forestry at Oregon State University, the USDA Forest Service Pacific Northwest Research Station, the USDI National Biological Service, and the Bureau of Land Management, plus other federal and state agencies, forest industry, county and city governments, and the Oregon Small Woodlands Association. The intent of the program is to provide resource managers and the public with information on managing fish, timber, water, wildlife, and other resources of the Oregon Coast Range. To find effective ways to manage these diverse resources, the COPE Program integrates research, education, and scientific disciplines.

Ecosystem Management Research Program for the Pacific Northwest. The goal of this new research program of the U.S. Environmental Protection Agency in Corvallis, Oregon, is to contribute to the ecological understanding and approaches that federal, state, tribal, and local governments will need if they are to implement ecosystem management effectively in the Pacific Northwest. The program defines four objectives, which are believed to represent the four general ecological research areas required to support ecosystem management. They will:

- Develop and demonstrate a general ecological assessment process, along with the associated analytical tools, dealing with multiple endpoints and multiple stressors across multiple spatial scales, that will allow managers to define realistic environmental goals; assess current ecological conditions relative to those goals and identify major environmental problems; evaluate and compare the ecological consequences of alternative management strategies; and target geographic areas for protection, restoration, or other management actions.

  An **endpoint** is defined as an ecosystem good, service, or societal value selected to serve as the focal point for management decisions and assessments. Examples include sustainable fishery yields and biological diversity. A **stressor** is defined as any chemical, physical, or biological entity or activity that can induce an ecological effect. A stressor may be natural or it may result from human activity.

- Advance the understanding of ecosystems, ecosystem dynamics, and ecosystem responses to human activities to reduce uncertainties in ecological assessments and improve confidence in ecosystem management decisions.

- Develop and demonstrate a spatial framework that provides a common, effective basis for ecological assessments at multiple spatial scales, environmental goal setting, and extrapolation of research results.

- Develop and demonstrate ecological monitoring designs that meet the needs of adaptive ecosystem management and are integrated across ecosystem types, spatial scales, and monitoring programs in different agencies.

The program has seven research components: regional biodiversity, watershed/ecoregion, riparian areas, coastal estuaries, integrated monitoring, ecological-socioeconomic linkages and technology transfer.

Three recent research projects studied patterns and relationships at the landscape scale, a field of increasing importance for managing natural resources.

Ripple *et al*. (1991), under the assumption that wildlife ecology and behavior may strongly depend on the nature and pattern of landscape elements, studied the use of spatial statistics to quantify the landscape pattern caused by the patchwork of clearcuts made over a 15-year period in the western Cascades of Oregon. In their paper, forest patches were digitized and analysed to produce both tabular and mapped information describing patch size, shape, abundance and spacing, and matrix characteristics of a given area. The authors also developed a GIS fragmentation index which is a function of the distances between the cell of a grid to a certain patch type. The GIS index was found to be sensitive to patch abundance and to the spatial distribution of patches. A comparison of the spatial statistics calculated for two years indicates an increase in forest fragmentation as characterized by an increase in mean patch abundance and a decrease in interpatch distance, amount of interior natural forest habitat, and the GIS fragmentation index. The authors conclude, that such statistics capable of quantifying patch shape and spatial distribution may prove important in evaluating the changing character of interior and edge habitats for wildlife.

McGarigal and McComb (1995) determined how changes in landscape structure (both composition and configuration) affect bird populations in the spatially and temporally dynamic forest landscape of the Oregon Coast Range. They developed FRAGSTATS software to quantify the configuration of the landscape. The authors conclude that, contrary to the idea that habitat fragmentation is detrimental to species that specialize on a particular habitat, most species that exhibited significant relations with habitat configuration in the study were associated with the more fragmented distribution of habitat. The results suggest that landscape structure at the scale of small 300-ha watersheds in the central Oregon Coast Range may have only a moderate effect on bird abundance. Vertebrate population dynamics in forests being fragmented by timber management activities are likely to differ from those in forests being fragmented by urbanization and agricultural development.

The work on the Camp Pendleton area, California, edited by Steinitz (1996), explored how urban growth and change in the rapidly developing region between San Diego and Los Angeles might influence its biodiversity. The study was conducted by a team of investigators from several universities and agencies. Future change was studied at four scales: several restoration projects, a subdivision, a third-order watershed, and the region as a whole. Regional change is simulated via six alternative projections of development to the year 2010. The first scenario is based on the current local and regional plans. Five alternative scenarios provide a method for exploring and comparing the effects of different land-use and development policies relating to biodiversity. All alternatives accommodate the population forecast for the region. A set of process models - - for soil, hydrology, fire, visual preference, and biodiversity - - is used to assess each alternative. The results from the evaluation of the six alternatives can be used by stakeholders as a source of information for making decisions. It is worth noting that the alternative that seeks to protect the most significant habitat areas via private conservation produces the best overall result.

The question, "How should the role of **disturbances in the ecosystems at all scales** be integrated with management?" was considered by Garman *et al.*(1995) as an important research emphasis, for several reasons. First, designing landscapes based on the historical variability in disturbance patterns is of interest. The underlying philosophy is that maintaining an ecosystem within its range of natural variability provides an ecological template for sustaining species and ecosystem processes (Swanson *et al.* 1993). Second, because ecosystem management planning extends over long periods, the chance for natural disturbance events to occur is greater, so a land-use design must take the probability of these events into account.

These examples show that in the Pacific Northwest, long-term, landscape scale, integration (between scientific disciplines, between small and large scale, between short and long-term, between management and science), and disturbances are four major concerns for research.

3. A vision of managing natural resources for sustainable development

3.1 Introduction

How should natural resources be managed for sustainable development?. Although tools for managing most of the natural resources are generally known and available, the answer is difficult for three main reasons:

(1) limited scientific knowledge on the long-term processes, reactions, and interactions in ecosystems;

(2) the difficulty to reaching consensus among the different groups of interest on the multiple objectives of management; and

(3) the challenge of defining sustainability.

The task is formidable and could seem impossible, but, as in many other situations in life, sustainable development is a learning process. If we want to succeed, we have to go through all steps of the process, one step after the other. To do so, we need an understanding of management of natural resources for sustainable development and a vision of implementing it. In the next section, I present some basic principles that are the logical consequences of the background and recent developments described earlier (see also figure 1). I introduce the notion of ecosystem based-management, its instruments (see also figure 2), its implementation (see also figure 3), and some related scientific challenges.

3.2 Principles of managing natural resources for sustainable development

Figure 1: Principles of managing natural resources for sustainable development

Managing natural resources for sustainable developement should:

- **tend towards sustainable use of ecosystem resources**
- **be holistic**
- **be ecosystemic**
- **be done with a landscape perspective**
- **have multiple objectives**
- **be based on sound science and good judgment**
- **take cognitive, emotional, and moral reactions into account**
- **should be based on the precautionary principle**

3.2.1 Managing natural resources for sustainable developmenet should tend towards sustainable use of ecosystem resources.

To move towards sustainable development, one objective with high priority should be the sustainable use of ecosystem resources. This objective is not trivial. Despite internationally accepted criteria, sustainability has severe limitations in its application, and many questions are still open (section 2.2). One is considering the quality of life of future generations, which means at least trying to avoid short-term solutions that aggravate long-term problems (Schulze *et al.* 1996). Often management can provide at least ecological improvements, rather than solutions for sustainability. Where management for sustainable development is truly possible, the cases should be described and used as models.

3.2.2 Managing natural resources for sustainable development should be holistic

People and their environment are one. This statement is true for the Earth, the ultimate ecosystem we want to sustain, as well as for ecosystems defined on smaller scales. People, plants, animals, microorganisms, and the environment are all connected in a great and complex network. Closed systems that function independently from other systems do not exist. A holistic approach is therefore necessary. Savory (1988) called holistic resource management an approach that treats people and their environment as one. He derives his approach from a view of ourselves and our planet as one ecosystem functioning through four rudimentary processes: the development of living communities (succession), the cycling of mineral nutrients, the cycling of water, and the flow of solar energy. The approach also establishes clear goals in all situations, and the use of what he has termed a "thought model" to enable us to "see the whole" we are managing.

An important management consequence of the holistic view is the need to include in the process, in so far as possible:

- The ecological, economic, technological, and social issues.

- The short-, mid-, and long-term.
- The different spatial scales: from the stand to the landscape.
- The interactions between the different elements in the management unit and the interactions between the management unit and external systems.
- Management as well as scientific information.

3.2.3 Managing natural resources for sustainable development should be ecosystemic

> Thinking holistically about sustainability means approaching it on an ecosystem rather than a species or product basis. It means thinking about the full array of species, processes, and structures and about their interrelationships, which underlies the productive potential of a given site or ecosystem. (Franklin 1993)

Because of the nature of ecosystem, human interventions usually affect not only one aspect of the manipulated ecosystem, but a series of components and processes. A timber harvest to obtain wood will not only decrease the standing wood volume of the forest but will also affect the soil, the water cycle, and the wildlife habitats. Similarly, the manipulation of a particular ecosystem may have important effects on the adjoining ecosystems. Typical examples are the effects of agricultural and forestry practices on streams and riparian areas. Ecosystem management implies processes in which the decisions are taken after an evaluation of the possible consequences for all key components and processes of the affected ecosystem **and** adjacent ecosystems at various scales.

3.2.4 Managing natural resources for sustainable development should be done with a landscape perspective

Local ecosystems like individual forest stands, riparian areas, and wetlands are not closed systems. They are interacting with other landscape elements. These interactions and the human manipulations done at a local level have at the landscape scale cumulative effects which can affect a whole region. According to Franklin (1993), planning at the landscape level is the only way that we are going to avoid undesirable, if not unacceptable, landscape dysfunction. As examples he mentioned the large-scale clear-cutting effects on streamflow in the Pacific Northwest and the linkage between the extent of erosional processes, such as landslides, and the size of the road system, especially on steeper topography. Also Anko (1994) and Salwasser and Pfister (1994) recognized the need to consider the forest not from the point of view of forest ecology alone, but also from the landscape ecological perspective. I believe that this is true for all types of natural resources. The main task of landscape ecology is to gain knowledge about the relationships among the building blocks of the landscape and, from these, about the functioning of the landscape as a system (Zonneveld 1991). In this sense landscape ecology is an important tool for managing natural resources for sustainable development.

3.2.5 Managing natural resources for sustainable development should have intersectoral multiple objectives

The nature of the objectives of managing natural resources for sustainable development is the result of many elements: all existing legal and political constraints, the holistic and ecosystem nature of such management, and the internationally defined criteria for sustainability, including biodiversity. Managing for a unique commodity is not an appropriate objective; objectives are based on a variety of issues corresponding to the identified ecological, economic, and social needs, or in other words, to the different functions of the ecosystems in the landscape. To illustrate I will use the results of a recent study about long-term trends and prospects in world supply and demand for wood and its implications for sustainable forest management (Solberg *et al*. 1996). The team came to the conclusion that world forests are biologically capable of supplying the quantity and type of wood consistent with the highest demand projections. Therefore, their assessment is that the outlook for demand for and supply of wood does not require a warning of impending crisis to the global forest policy debate. However, the global long-term outlook is for a steadily rising demand for wood and its products, and for the services of the forest, and a declining area of forest available for their production. These trends will result in increasing pressures on wood supply arising from the growing importance of non-wood goods and services and demands for environmental protection. This situation suggests that an immediate priority is the need to strengthen **intersectoral decision making affecting land use** and therefore the need to manage with multiple objectives concerning ecological, economic, and social issues. Similar conclusions could be drawn at lower geographical scales and for other types of ecosystems as well -- for example, aquatic systems, especially important as a constraint on agricultural land. However, a vital question has to be answered: "Which are the processes to be used for setting the objectives, and who should be involved?".

3.2.6 Managing natural resources for sustainable development should be based on sound science and good judgment

That scientific knowledge represents an important basis of managing natural resources for sustainable development is generally accepted. Thomas and Huke (1996) were convincing when they wrote:

> The quality of policy and ecosystem management decisions is highly dependent on the quality and quantity of available information and science. Developing the foundation for ecosystem management will require not only sound science, but the right science - knowledge and understanding of how major ecosystems function; how they can support and tolerate human use; and how policies and management decisions affect resource use, the environment, and recovery.

Ecosystem research in the world is improving that knowledge through the publication and dissemination of its results.

Sustainability is a social choice with limitations. Seeking to balance ecological, economic, and social considerations can induce many different, sometimes opposite views. To reach consensus in fixing the goals and the objectives for the society's use of natural resources, and to obtain the involvement, understanding, and support of all concerned groups in the implementation of management are among the most critical and difficult tasks of managers and policy makers. These challenges can be best met by basing decisions not only on sound science, but also on good judgment. I understand the term "good judgment" as does Yankelovich (1991), when he uses the term "public judgment" to mean a particular form of public opinion that exhibits more thoughtfulness, more weighing of alternatives, more genuine engagement with the issue, more taking into account a wide variety of factors than ordinary public opinion as measured in opinion polls, and that has more emphasis on the normative, valuing, ethical side of questions than on the factual, informational side. In management of natural resources, good judgment should also include more consideration of long-term considerations.

3.2.7 Managing natural resources for sustainable development should take cognitive, emotional, and moral reactions into account

In general, to obtain the desired goods, services, and states, ecosystem manipulations are needed, like harvesting, harvesting exclusion, hunting, hunting exclusion, road construction, and many others. Often, needed ecosystem manipulations or restrictions agains manipulations are susceptible to cognitive, emotional, and moral obstacles which can seriously slow down the management process. The same is true for environmental issues like air pollution, climate change, or energy production. Yankelovich (1991) defined cognitive obstacles as the difficulties associated with perceiving thinking, judging, connecting, sorting out, and absorbing information. For him, emotional obstacles involve coping with a wide swathe of feelings and the defenses associated with them: hope, fear, anxiety, idealization, anger, denial, avoidance, resignation, bitterness, self-agrandizement, self-esteem, and so forth. The moral obstacles involve conflicts between personal desires and commitment to others. We can improve the effectiveness of management by identifying these obstacles and, if necessary, by taking them into account, for example by developing an adequate information strategy and including social scientists in the process.

3.2.8 Managing natural resources for sustainable development should be based on the precautionary principle

Principle 15 of the Rio Declaration stipulates that

> in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The precautionary principle raises an extremely interesting, important, and complex issue: the role and the management of risks and uncertainties. In the long run, its application in managing natural resources should allow us to maximize the chance to sustain the different ecosystem functions.

3.3 Ecosystem-based management

When natural resources are managed for sustainable development, managers recognize that they cannot manage **all** components, processes, and interactions of the ecosystems. Rather, they are manipulating particular aspects of the ecosystems, with a view to sustaining desirable characteristics and by taking into account, as far as possible, inputs, processes, interactions, and outputs of the ecosystems. For example, they can find out what ecosystem composition and structure is needed for producing wanted commodities, wildlife conservation, erosion protection, water quality, or recreation and try to intervene accordingly, keeping the principles for managing natural resources for sustainable development in mind (section 3.2). Therefore I prefer to think in terms of **ecosystem-based management,** rather of ecosystem management. An important advantage of this formulation is that it can be used with all types of natural resource management issues: ecosystem based land-use management, ecosystem based management of forest resources, ecosystem based management of water resources, ecosystem based wildlife management, ecosystem based wetland management, and ecosystem based watershed management, and so on.

Ecosystem-based management can be seen as a systematic process, based on good judgment and sound science, and aiming, for a defined area, at the sustainable use of natural resources, by increasing the ecological sensitivity and content of management practices, and by integrating economic, ecological, social, and technological considerations, over both the short and long terms, from the site to the landscape-scale ecosystem.

Ecosystem-based management will help people to use natural resources and simultaneously to maintain productivity for the benefit of future generations, to protect particularly valuable ecosystems, to restore degraded habitat, or to rehabilitate altered ecosystems.

Despite the argument in favor of the term ecosystem-based management, we should not forget that the main issue for sustainable development is **how natural resources are managed, and not the terms we use**. The next section describes briefly the main instruments of ecosystem-based management and some aspects of its implementation.

3.4 The instruments of ecosystem-based management

Figure 2: The instruments of ecosystem-based management

- **Integrated approach**
- **Participation**
- **Adaptive management**
- **Monitoring and evaluation**
- **Clearly defined, but flexible and adaptive process**

The main instruments of ecosystem-based management are integration, participation, monitoring, adaptive management, and systematic process.

3.4.1 The integration

Lang (1990) presented an excellent and short justification for integration:

> Resource development today faces formidable problems. Demand for resources is accompanied by differing perceptions of their values, conflicts over their use, and concern about the natural and human environments affected. These problems are exacerbated by fragmented jurisdiction over the resource base, ambiguous government policies, lengthy review processes and weak regulations. Resource planners, developers and managers are responding to these problems by seeking more integrated approaches that will enable their projects and programs to deliver as many benefits as possible, within acceptable limits of social and environmental impact, and with minimum conflict and cost.

The recognition of the need for integration in managing natural resources is not new. An overview of the evolution of the concept in the United States and in Canada can be found in Mitchell (1990). Because land resources are used for a variety of purposes that interact and may compete with one another, the international community recognized at the Rio Summit the desirability ofplanning and managing all uses in an integrated manner (Agenda 21, chapter 10). Conferences with the theme of integration have been organized-- for example, the International Conference on Sustaining Ecosystems and People in Temperate Forests: Integrating Conservation of Biological Diversity with Social and Economic Goals, British Columbia, 8 - 13 September 1996. Clark *et al.* (1996) explored the concept and meaning of integration with particular emphasis on fostering better understanding of social, cultural, and economic considerations. They summarized the literature and presented different perspectives on what integration is and is not. They examined some barriers and offered an approach for improving our capacity for effective integration, both in the short and long terms. They considered coordination, interdisciplinary teams, analytical science, modeling, and collaboration as means to achieve integrated resource management.

In my view, integration in managing natural resources should mean:

- Achieving agreement on the problem, issue, questions, and goals, including consideration of different ecological, economic, and social points of view and interests.
- Bringing together existing information about the managed as well as the unmanaged resources in the managing unit, including the processes and interactions within and between the ecosystems.
- Linking together the small scale and the large scale issues.
- Deciding on a course of action only after having evaluated the possible ecological, economic, and social impacts and possible side effects of the foreseen manipulations on the considered ecosystem, on the adjoining ecosystems and on the whole managed unit over time.
- Recognizing the middle and long-term consequences of the planned short-term actions.
- Synthesizing the existing scientific knowledge from the relevant disciplines.
- Linking managers, policy makers, scientists and the public.

Integration fosters appropriate choices and trade-offs, thus optimizing sustainable productivity and use.

3.4.2 Participation

How can the need to balance ecological, economic, and social issues be effectively satisfied? One approach is the participation of all the concerned parties in the management process. The stakeholders can be invited to help set goals, analyze the situation, and develop improvements and solutions. Shindler and Neburka (1996) identified attributes for the success of public participation in forest communities. They compared five different long-term planning processes that occured between 1989 and 1995 in the Pacific Northwest. Eight attributes of success were identified by group participants. For example, it came out that groups where members are selected by the agency for their understanding of the issues and their willingness to commit to a group process are more effective. Also, meetings that are structured to promote full group interactions, rather than simple information sharing and feedback, are much more productive. Management by participation is already practised with success in different cases, for example in the Elliott Forest in Oregon, or in the Canadian Model Forests Program (Science Branch Canadian Forest Service, 1996). It is clear that the participation process will not only depend on the main management issue, but also on the ownership situation: federal, state or private land.

3.4.3 Monitoring and evaluation

The term monitoring is used in two different ways. Firstly, it implies the measuring and assessment of data in relation to key variables to determine whether or not objectives or standards have been met. However, it can also signify the collection of data with the aim to detect trends and understand how a system is functioning (Canadian forestry terminology, 1988). Spellenberg (1991) summarized the value of biological and ecological monitoring by the following objectives:

1. Monitoring as a basis for managing biological resources for sustainable development and resource assessment.
2. Monitoring so that ecosystems and populations can be managed and conserved effectively.
3. Monitoring land use and landscapes as a basis for better use of the land; that is, combining conservation with other uses.
4. Monitoring the state of the environment - using organisms to monitor pollution and to indicate the quality of the environment.
5. Monitoring as a way of advancing knowledge about the dynamics of ecosystems.
6. Monitoring of insect pests of agriculture and forestry so as to establish effective means of control of those pests.

Management without monitoring is like playing football without recording the score. Effective monitoring helps managers to follow the consequences of their interventions, to be informed about unexpected events, and to measure deviations from the management objectives. In adaptive management, a monitoring philosophy is needed that fits with the broad **learning goals** (Bormann *et al.* 1966).

Monitoring and evaluation processes must be scientifically and legally defensible, otherwise they are of doubtful value. The quality and the relevance of monitoring depends on its objectives, its design, the methods used for measuring the variables, the variables and the processes chosen, the methods used for the analysis of the data, the interpretation of the results, and the way the results are disseminated.

3.4.4 Adaptive management

In managing biological resources we are confronted with the complexity of ecosystems, with long-term processes, with unpredictable natural disturbances as well as with human influences. Even with the best available science complete answers to all management questions will not be attainable. We will always have to manage under uncertainties and will need to accept the inevitable mistakes as learning experiences. These realities were recognized by many authors and led to the notion of adaptive management, defined by Holling (1978) as an interactive process using techniques that not only reduce uncertainty but also benefit from it. Walters (1986) asks how we should proceed to develop better understanding of managed system responses and potentials in a world of great uncertainty, limited research resources, and continuing pressure for more intense exploitation. His answer is to treat management as an adaptive learning process, where management activities themselves are viewed as the primary tools for experimentation.

Adaptive management is an important issue in the Pacific Northwest. The Forest Ecosystem Management Assessment Team (FEMAT) report (1993) proposed the creation of 10 adaptive management areas across Washington, Oregon, and northern California. These areas became realities in December 1994 with Judge Dwyer's decision affirming the legality of the Northwest Forest Plan (Stankey and Shindler 1996). Bormann *et al*. (1994a) presented a systematic approach to adaptive management to simultaneously manage at the regional, provincial, and watershed scales and to reorganize the activity of agencies to better support the concepts of adaptive management. They proposed a strategy to improve management by making better decisions, improving public participation, developing science-based management, and using a systematic approach. They also recommended reorganizing management activities into four groupings that support the desired function of the whole system: adjustment; linked, not single actions; feedback, including monitoring; and information synthesis. Stankey and Shindler (1996), in a study of the FEMAT adaptive management areas, identified several barriers confronting effective implementation of the adaptive management. They presented a set of four propositions that address these potential barriers: (1) area boundaries must possess social meaning for stakeholders; (2) a focus on adaptive management areas will highlight limitations in scientific knowledge; (3) management of the adaptive management areas will highlight differences in how the world is perceived; and (4) effective management of the adaptive management areas will challenge existing institutional arrangements.

Bormann *et al*. (1996) explored new possibilities for achieving complex management goals on Federal lands by applying adaptive management. In their comprehensive paper, they used the term adaptive management to describe an approach to managing complex natural systems that builds on common sense and learning from experience to include experimenting, monitoring, and adjusting practices based on what was learned. In order to achieve balanced learning among citizens, scientists, and managers, they advocated to add learning and adapting as management goals. For speeding learning and to reduce the risk of biased or incorrect interpretations, they suggested incorporating scientific methods in everyday management actions where possible.

I have no doubt that adaptive management can be an efficient tool for managing natural resources for sustainable development. Adaptive management, as a combination of management and scientific methods, is a way to overcome the limitations of science as well as of management itself. Research is often in difficulty to answer questions at large spatial and temporal scales. Management, when based on only one course of action, has limited value as a learning process. Adaptive management can be considered as a common ground where managers, scientists, and citizens can try to learn to meet society's needs and wants while maintaining ecological capacity (Bormann *et al*. 1996). As an example I would like to mention what Bormann *et al*. (1996) called experimental management. This is a type of adaptive management in which suites of policies are directly compared in scientifically designed "management experiments" which become the focus of monitoring and evaluation. In Oregon, this technique is being tried at stand scales as well as at larger scales.

3.4.5 Managing natural resources for sustainable development should be a clearly defined process

To be effective managing natural resources for sustainable development should be a clearly defined, but flexible and adaptive process including, for the management unit: defining the management framework; formulating general objectives; analyzing ecological, economic, and social conditions of the unit; formulating specific objectives; elaborating and evaluating different management alternatives; selecting the alternatives to be adopted; planning the execution; executing the plan; monitoring and assessment; and adapting.

Miller *et al*. (1994) presented the process steps to define a problem that calls for action, to make a decision, to plan effectively, and to understand cause and efffect.

3.5 Implementation of ecosystem-based management

The main principles of managing natural resources for sustainable development were listed in 3.2. Here, based on these principles, is an overview of a possible approach for management, a systematic and iterative process based on a series of relevant management questions.

- **What are the guiding principles and what is the vision for management?**

- **What are the goals and general objectives?**
  These questions allow us to become aware of the reasons for managing and the most logical lines to follow.

- **How intense should the planning process be?**
  This step allows us to adapt the intensity of the planning process to the general objectives. Often, extensive planning, based on a minimum of information and actions, can be sufficient.

- **Who should belong to the planning team?**
  A good way to assure participation of the stakeholders is to invite them to participate at the beginning of the planning process. To avoid frustration, the role of the planning team and the rules of the game should be clearly defined.

- **What are the available sources of information?**

- **What is the current situation and what are the key issues in this management unit?**
  The depth of the analysis depends on how intense a planning process was chosen. The current status and the likely changes in the following items should be considered:
  - Geographical limits and landscape characteristics of the management unit (size, configuration and distribution of the different land-use and land-cover types, ownership situation)
  - Ecological characteristics (inputs, processes, functions, interactions, flows and outputs of the different ecosystems in the management unit; interactions between the different ecosystems within the management unit)
  - Economic characteristics of the management units (expenditure, income, subsidies)
  - Social characteristics (involved people; traditions; political factors to be considered)
  - Legal characteristics (relevant legislation, standards and guidelines)
  - Relationships between sites, watershed, and landscape characteristics
  - Relationships between short-term and long-term characteristics
  - Existing opportunities and risks
  - Key issues to be considered
  - Available tools (money, people, infrastructure, technology)

- **What are the specific management objectives?**
  The specific objectives should be formulated in terms of criteria and indicators, defining and quantifying sustainable development, and include ecological, economic, and social components. We can follow the three steps proposed by Bormann *et al.* (1994), for calculating sustainability: select candidate goods, services, and states desired by society; determine ecosystem patterns and processes which are needed for the desired goods, services, and states; and jointly evaluate and set priorities among societal demands and ecosystem patterns and processes. Learning objectives should also be included.

- **What alternative courses of action could be used?**
  To find out the optimal solution, generating different management alternatives which should allow us to reach the formulated objectives, is useful, perhaps essential.

- **What are the mid- and long-term effects on the defined criteria and indicators of each alternative?**
  On the basis of given assumptions, the effects of the different courses of action on the ecological, economic, and social criteria and indicators are simulated. In particular, we evaluate the possible effects of the proposed manipulations on the elements, processes, and interactions in this ecosystem, as well as on adjacent ecosystems.

- **Which management alternatives should we choose and how should they be designed?**
  This step is based on comparing the elaborated alternatives, including their cost/benefit ratios. Bormann *et al.* (1996) advocated comparing more than one alternative at the same time to increase the rate of learning.

- **Which are the priorities?**
  Knowing that everything cannot be done immediately, priorities have to be defined and weighted, based on an analysis of budget and timelines. This step is a basis for the implementation.

- **Plan the implementation**
  The plan now should answer the questions What has to be done? Why? Who has to do what? When? How? and How much does it costs?

- **Plan the monitoring and the assessment**
  Monitoring is a learning process and informs us about the effects of our management. Therefore, monitoring and assessment are based on the criteria and indicators used to define the management objectives, and what will be monitored, how, and at what intervals is contained in the original design.

- **Inform the concerned organizations and persons**
  Relevant and truthful information is the basis of good communication between people. Who should be informed, when, and about what should also be described in the planning process.

- **Implementation, monitoring and assessment**
  Essentials in this step are the choice of the most competent people and a clear mission statement, based on the planning document.

- **Adapt the management**
  Results of management rarely correspond precisely and entirely to the planning. Assessment informs us about deviations from what was expected and their causes. The management strategy may then be adapted (Noss 1993; Bormann *et al.* 1994).

Figure 3: Questions to be answered for the implementation of ecosystem-based management

- **What are the guiding principles and the vision for management?**
- **What are the goals and general objectives?**
- **How intense should the planning process be?**
- **Who should belong to the planning team?**
- **What are the available sources of information?**
- **What is the current situation and what are the key issues in the management unit?**
- **What are the specific management objectives?**
- **What alternative courses of action could be used?**
- **What are the mid- and long-term effects on the defined criteria and indicators of each alternative?**
- **Which management alternatives should we choose and how should they be designed?**
- **Which are the priorities?**
- **Plan the implementation**
- **Plan the monitoring and the assessment**

- **Inform the concerned organizations and persons**
- **Execution, monitoring, and assessment**
- **Adapt the management**

3.6 The scientific challenges

The contributions of science are numerous and valuable but many uncertainties remain about the ecosystem-based management of natural resources. Baker *et al.* (1995) identified the following major research needs: considering multiple endpoints, multiple stressors, and their interactions and trade-offs at multiple spatial and temporal scales; synthesizing the relevant information from many scientific disciplines; and presenting scientific information in a user-friendly format useful for policy makers and understandable to the wide array of stakeholders.

The following list is an attempt to illustrate some general questions about natural, social, and technical issues, and that could be used to define **ecosystem-based management research priorities**:

How do changing socioeconomic conditions like population growth and increasing energy consumption influence the social choices related to use of natural resources?

Given the different interests and view points, how can we reach agreement in defining the ecological, economic, and social objectives for managing natural resources? Who has the authority to resolve conflicting points of view?

How can we assure the involvment of all concerned groups in implementing the management of natural resources?

How do adjoining ecosystems interact and what are the effects of these interactions at the landscape scale?

How do human activities, including management and engineering, affect the ecological integrity and the health of manipulated ecosystems, e.g.their composition, structure, processes, interactions, state and dynamic, as well as their ability to satisfy the economic and social needs of the society, in both the short and long-term ?

How do human manipulations of a particular ecosystem affect the adjoining ecosystems as well as the landscape as a whole, in both the short and long-term?

Given the changing economic conditions and available scientific knowlege, how do we understand sustainable use of natural resources? In particular, what should we sustain and at what spatial and time scales?

Which criteria and indicators are feasible to measure sustainability? How can these criteria and indicators be used in ecosystem-based management?

How can we best use the available scientific knowledge (both biological and social) and engineering technology for the multiple and sustainable use, protection, restoration, and rehabilitation of all types of ecosystems to serve as habitat for wildlife (especially for endangered species), to produce commodities, and to satisfy social needs?

How should the role of disturbances in ecosystems at all scales be integrated with management?

How can we monitor the ecological state and dynamics of ecosystems and their actual and potential capacity to fulfill the economic and social needs of society?

How can we describe and identify the risks of degradation to which ecosystems can be exposed? How can we take account of these risks in management?

How can we implement adaptive management in order to take account of the existing uncertainties and of the evolution of knowledge?

What does ecosystem-based management cost? Who gains and who loses?

4. Conclusions

People, worldwide, are becoming aware of the need to use our natural resources with the life quality of current and future generations in mind. Policy makers, managers, scientists, governments, private industry, and non-governmental organizations are developing, sometimes together, new visions for their management. These new visions require a shift from mainly commodity-production oriented management towards a management addressing simultaneously ecological, economic, and social issues.

This change of paradigm is not without contradiction, controversy, and tension. For example, the concept of ecosystem management developed in the United States is still defined and interpreted in too many different ways. However, the concept also includes enough useful principles that, if applied in practice, it can allow society to take some steps in the direction of sustainable development. I prefer the term ecosystem-**based** management because it describes better what can be done: people can manage natural resources with the **whole ecosystem in mind**, also using ecosystem concept to allocate attention across both internal interactions and between systems, though we cannot expect to manage everything in the whole ecosystem to produce natural resources.

The key issue in managing natural resources for sustainable development is to find the balance between production and the productive capacity of the ecosystems - - locally, regionally, and globally, and in both the short and long-terms. One major challenge, is how to integrate the ecological, economic, and social needs of society, while considering the interactions and processes within and between the different ecosystems, and taking into account the natural and human factors affecting the management unit. There are successes, but there are also emerging problems that must be addressed. A basic condition for progressing is, of course, that managers, scientists, policy makers, teachers, and all concerned people are recognizing the need to act with a view towards **future generations** and are accordingly willing to implement the principles of ecosystem-based management.

My paper is one of the many conceptual contributions to the management of natural resources for sustainable development. Far fewer publications are about implemented examples. The next step should be to apply and test the presented ideas in different case studies and to try, through research and management, to answer the unanswered questions.

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