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Designing a framework for dynamic monitoring of ecosystem changes in the Lugu Lake region

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Key words: Lugu Lake, dynamic monitoring of ecosystem changes (DMEC), remote sensing, field investigation

SUMMARY

It is important and necessary for sustainable management of regional ecosystems to establish a framework for dynamic monitoring of ecosystem change (DMEC). For sustainable ecosystem management of the Lugu Lake region, the key issues addressed in DMEC are monitoring range, principles, intervals, site and indices, which can be used to create a framework for long-term DMEC for a region. This paper puts forward a new method to combine remote sensing with field investigations to achieve accurate and appropriate changes in a regional ecosystem. Because regional ecosystem change is closely related to local inhabitants, the authors also consider the participation of these people. Finally, the use of DMEC to provide a framework for decision-making and sustainable management of a regional ecosystem is described.

INTRODUCTION

Human activities have caused extensive and rapid changes to natural ecosystems. Because these changes directly influence human welfare, research on regional ecosystem change has received much attention, and is an important aspect of global change research. The simplest method to monitor ecosystem change is to collect long-term data on structure, function and biodiversity of the ecosystem, so as to understand trends and drivers that can be used for decision-making in ecological protection, resource utilisation and environmental management (Yu *et al.* 2002). Regional ecosystem monitoring needs to encompass long-term patterns and processes of each type of ecosystem within the region at different

spatial and temporal scales. Therefore, an accurate, low cost scientific system for monitoring and an effective operational framework are essential for dynamic long-term monitoring of regional ecosystem changes.

Several global change networks for ecosystem research have been developed, and methods for ecosystem monitoring are constantly improving. Among these networks are the Environmental Change Network (ECN) in the UK, the Long-Term Ecological Research program (LTER) in the USA, the Terrestrial Ecosystem Research Network in Germany, the International Long-Term Ecological Research (ILTER) and Global Terrestrial

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Observation System (GTOS) projects. In China, the Chinese Ecosystem Research Network (CERN 2006) was established in 1988, and includes 36 field stations in various ecosystems to monitor agriculture, forestry, grassland and water systems, five interdisciplinary centres and a synthesis centre. All the CERN stations engage in monitoring, research, experiments and demonstration projects, while the interdisciplinary centres are responsible for calibration of monitoring instruments and data quality control. The synthesis centre functions as a data exchange engine for interdisciplinary research. Through its long-term monitoring, research, experimentation, demonstration and extension, CERN has served as an important facility to control and understand desertification, soil erosion, salinisation and eutrophication in China. Most of the fixed stations are sponsored by special funds and run by local professional departments, their distribution is scattered and their range limited. Hence, the existing stations cannot meet the requirements for monitoring every regional hotspot ecosystem. In hotspot regions, it is necessary to establish independent ecosystem monitoring systems where the priority is management and research for decision-making by the local ecosystem management authority (Fisher and Kus 2003).

The Lugu Lake region in Yunnan Province is a hotspot natural landscape around a plateau lake where the Mosuo people have lived for centuries, and their characteristic matriarchal culture is well preserved. Lugu Lake region is well-known for its natural ecosystems and cultural heritage (Guo *et al.* 1996; Zhou 2001; Ye 2006). However, in recent years, along with rapid development of society and the economy, especially development of a tourism industry, the natural environment and cultural heritage in this region have been subject to great human disturbance. Because of the natural landscape of the lake and the Mosuo people's unique matriachal culture, Lugu Lake region has become one of the most important areas requiring ecosystem conservation and protection, and extensive concerns over the long-term survival of the ecosystem and its people have been raised by ecologists, economists and social scientists.

To guarantee sustainable management of this regional ecosystem, it is necessary to establish a suitable framework for dynamic monitoring of ecosystem change (DMEC). Building DMEC in the Lugu Lake region will provide a service for

decision-makers for sustainable management of the ecosystem in this special region. The key issues for DMEC in the Lugu Lake region are the monitoring range, intervals, extent of the site and developing an index to establish a framework for long-term DMEC. This is the focus of the present paper and includes step-by-step analysis of the procedures developed.

FRAMEWORK FOR DMEC IN THE LUGU LAKE REGION

Defining the monitoring range

Lugu Lake region includes the whole of the lake around which most Mosuo people live, the surrounding topography, landscape, endemism and socio-economic characteristics. In terms of geobiology, ecosystem integrity and landscape ecology, the region can be zoned into three parts: Yongning River watershed (1609 km²), Lugu Lake scenic area (508 km²) and Lugu Lake watershed (247 km²) (Figure 1). The Lugu Lake scenic area was planned by the local government and is the main area under intense human disturbance and, therefore, the main monitoring area. The area outwith Lugu Lake scenic area has less human disturbance, and information on ecosystem changes in this area are useful for comparison. The whole monitoring area covers 60 × 60 km, centred on Lugu Lake (Figure 1). Because Lugu Lake watershed is in the lower reaches of the Yongning River, and is affected directly by ecosystem changes in the upper reaches of the river, the monitoring area should include the whole watershed of Lugu Lake and Yongning River. In this research, the watershed boundaries of Lugu Lake and Yongning River were generated from a digital elevation model (DEM) with a scale of 1:250000 using Arc View 3.1 and a SWAT model (Bärlund *et al.* 2006).

Establishing monitoring principles and intervals

The aim of DMEC in Lugu Lake region is to detect ecosystem changes and to support decision making for sustainable ecosystem management. Some general principles are required:

1. As Lugu Lake is the home of the Mosuo people, DMEC is combined with ethnologic, social and economic investigations.

Figure 1 Sketch map of whole monitoring area

2. DMEC includes remote sensing data and field investigations.
3. Permanent fixed sites and temporary monitoring sites were established, and different sites monitor different aspects over different time periods.
4. The cost and feasibility of monitoring were considered.
5. Participation of the local people was essential.

For biological and soil factors of DMEC, the monitoring interval is 5 years. As water environment factors are sensitive to environmental change, these are monitored every month. The monitoring frequency of Lugu Lake watershed and the scenic area is higher than that outwith these areas. The watershed is monitored once per year, and the scenic area every 5 years. The period for remote sensing data acquisition is 5 years.

Selecting monitoring sites

Selection of a sampling strategy at sites affects monitoring results, especially for biodiversity monitoring (Chiarucci *et al.* 2001). Accordingly, field sites include permanent and temporary sites. The permanent terrestrial sites were determined according to geographic coordinates and spatial distribution of the ecosystem, and 16 permanent terrestrial sites, one site per 15×15 km area, were established within the total monitoring range of 60×60 km. Among the 16 permanent terrestrial sites, three sites are in the Lugu Lake watershed, two outwith the watershed but in the scenic area, seven outwith the scenic area but in Yongning River watershed,

and four in the monitoring area outside the Yongning River watershed. The ecosystem types of the 16 permanent terrestrial sites are grassland, forest and farmland, and the corresponding ecosystem type and position in the 15×15 km area were determined by representative sampling. There are four grassland sites, four farmland sites and six forest sites. For aquatic ecosystems, including wetland, river and lake, there are ten permanent sites, three for wetland ecosystems, three for the river ecosystem (upstream in the forest, mid-stream in farmland, and downstream in the inhabited area), and four for Lugu Lake (including the inlet and outlet of the lake).

Investigations of inhabitants include social, economic and cultural studies by interviewing local people. Representative local families were selected for long-term monitoring and differences in economic incomes between different villages are considered.

Monitoring indices and data collection

Monitoring of ecosystem changes depends on objective observation and measurement, not subjective evaluation. Indices of ecosystem monitoring are items and parameters that characterise the situation and any changes. With respect to the regional ecosystem in Lugu Lake, monitoring involves methods to measure ecosystem services, structure and sustainability. Synthetic observation is applied to ecosystems which have commonalities, and special monitoring is used for unique ecosystems. For example, ecosystems such as farmland, forest and pasture have the same essential elements of biology, soil and atmosphere and can be sampled and monitored together. At the same time, individual assessment needs to be carried out for unique ecosystems. For the farmland ecosystem, it is necessary to investigate crops, fertiliser use, and plant nutrient content. For the forest and lake ecosystems, the volume of timber and structure of the forest stand and other essential characteristics were investigated and monitored.

The index selected should include unambiguous ecological data that are easy to measure, repeatable and highly sensitive. For sharing data and cooperative research between regions, index selection must reach international and national standards. Table 1 shows the monitoring indices and corresponding manipulation of data for the region.

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Work flow for ecosystem monitoring

A precondition for monitoring the regional ecosystem is to build a baseline database for background information. In this study, the data from satellite images in 1990 constituted baseline and background information. Thereafter, dynamic data on farmland, forest, pasture and human environments were captured through periodic remote sensing images, and the indices from ground investigations and mechanisms driving ecosystem changes were compared and analysed. Together, this information allows assessment of benefits and losses that can be used to develop a

strategy for ecosystem management that will provide information for decision making and sustainable management of the ecosystem. The work flow involved in monitoring is shown in Figure 2.

DISCUSSION

Combining remote sensing and field observations

By combining remote sensing and field observations, representative and comparative data on the status quo and trends in the ecological environment can be obtained that provide scientific

Table 1 Monitoring indices and data collection for the Lugu Lake region

Objectives	Items	Index	Data
Integrated ecosystem monitoring	Ecosystem structure	Variation in area; Changes to ecosystem	Remote sensing; Establishing ecosystem type
	Biodiversity	Landscape and ecosystem diversity	Remote sensing; Calculating landscape index
	Landscape pattern	Fragmentation index; Connectivity index	Remote sensing; Calculating landscape index
	Biology	Cover; Community; Succession; Phenology	Investigation of field area; Remote sensing
	Soil	Physical and chemical characteristics	Investigation of field area based on CERN
	Moisture	Water physical parameters; Water chemistry	Investigation of field area based on CERN
	Atmosphere	Criterion index from automated meteorology	Investigation of field area based on CERN
Monitoring specific ecosystems	Farmland ecosystem	Crops; Fertiliser; Plant features	Investigation of field area based on CERN
	Forest ecosystem	Volume of timber; Forest age structure	Field and remote sensing investigations based on CERN
	Lake ecosystem	Bottom characteristics of lake	Investigation of field area based on CERN
Human systems	Marriage	Percentage of Axia relationships; Inter-marriage with other ethnic groups	Field investigation of households
	Economics	Income per capita; Energy consumption; Tourism income	Field investigation of households
	Welfare	Education; Medical facilities	Field investigation of households
	Ownership of land	Individual, collective and state-owned land	Field investigation of households

Figure 2 Work flow for ecosystem monitoring

support for better use of natural resources and for implementing strategies of sustainable development. Based on the integration of information from regular remote sensing and quality information from field observations, we can develop a model of ecosystem services to evaluate trends in the Lugu Lake ecosystem. Only such dynamic monitoring of ecosystems will support the final aim of estimating and evaluating regional ecosystem services.

Local participation in regional ecosystem monitoring

The participation of local people is very important and necessary to obtain data for many of the indices. Local people know the local ecosystem and are aware of changes in regional characteristics of the ecosystem. The Mosuo people were unable to identify all the species in the monitoring area, but their long-term experience allowed them to recognise the rare species and gradual changes in the biome. More importantly, local people could identify exotic and recently introduced species.

The Mosuo not only know the practical value of the natural ecosystem and its biological resources, such as livestock, but have the capacity to reinforce the local ecology and environment if they are provided with government investment (Koto *et al.* 2004). Hence, local people are an essential component in monitoring dynamic changes and managing sustainable development of ecosystems.

CONCLUSIONS

In order to guarantee sustainable management of the Lugu Lake ecosystem, it is important and urgent to establish a complete framework for dynamic monitoring. Moreover, in the process of implementation, it is necessary to develop a scientific system consisting of easily measured, highly sensitive, sustainable and comparable indices. At the same time, considering the large scale and periodic features of ecosystem change, the sustainability of monitoring is essential so that the ecosystem management system serves regional sustainable development.

According to results from previous research and our studies and analysis of the Lugu Lake watershed, the combination of the remote sensing and field observations constitutes an efficient method for dynamic monitoring of ecosystem changes in this hotspot of human activity. Furthermore, these methods will improve the current lack of sufficient evenly distributed stations in the monitoring network for national ecosystems. Our results show that, in developing countries, adopting simple and feasible measures to improve ecosystem monitoring and changing human activities is important and necessary.

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