Thoughts on Integrated Monitoring of Ecological Environment at Provincial Level

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Abstract: The Law of Soil and Water Conservation entitles the administrations of water resources at various level to monitor ecological environment and to proclaim status of soil erosion periodically. Monitoring units of soil and water conservation approved by local governments are obliged to undertake this work. How to develop a monitoring program needs an overall and long-term concept. Particularity and objectives of ecological environment monitoring was discussed. Monitoring at provincial level may be divided into two levels: province-wide and at project level. Those indicators meaningful, sensitive to any disturbances, and simple to measure may be selected to test status of ecosystem stability and health. It makes sense to have an integrated sampling design, to set up permanent observation plots and to collect data, so that to have a relative timely, accurate understanding of ecosystems in the province. A program regarding sampling design, field methods, data analysis, documentation and implementation was detailed.

Key words: ecological environment; province wide monitoring; project level; sampling design; implementation program

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1 Introduction

Much attention is gradually being paid to project monitoring and evaluation in recent years, because the government realizes that monitoring is the basis for further project selection and decision making. The object of environment monitoring is of course an ecosystem, whether it is a relatively simple ecosystem such as desert, or complicated forest ecosystem, they are not separable. It is foreseeable that monitoring will be intensified. Presently, however, it is separated by different sectors and administrations at the provincial level. The provincial Environment Protection Administration monitors mostly air pollution, noise and water quality in the city, while the forest administration observes only forest growth, volume and so on. How to develop a monitoring program that integrates various resources and reacts to health condition of an ecosystem, is an inevitable question.

According to the Law of Soil and Water Conservation, the water administrations are entitled to monitor soil erosion and periodically stipulate the report on soil erosion. A network focused on monitoring of soil erosion is under construction since 2001, and first of all at province level. It is therefore urgent to know how an environmental monitoring program with emphasis on soil erosion must look.

Soil erosion is a consequence of many factors; conservation of soil and is started with biological, engineering and farming measures that are integrated with additional measures such as reconstruction of vegetation, improvement of farming techniques and construction of check-dams. Soil erosion monitoring and related conservation measures are concerned not only with the soil itself but also with the ecosystem in which they occur. A concept of soil erosion monitoring program is asked, but an integrated eco-environment monitoring program is the ultimate answer. Based on experiences at home and abroad, several points on developing a concept of an eco-environmental monitoring at provincial level are proposed.

2 Monitoring- definition and purposes

Some related terms come to mind when we think of monitoring. In order to understand clearly, it is necessary to distinguish these terms in relation to monitoring.

Research involves scientific and perhaps experimental

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work in order to understand basic functions, processes, and materials. Research normally produces the foundation of knowledge, information, and techniques upon which a monitoring program is built, but research is not monitoring itself.

Inventory is the collection of specific data on defined resources, such as a forest inventory done by the forest administration. It is usually a one-time "snapshot" of the resource. Inventories focus on defining spatial occurrence and distribution of the resource. Most inventories are one-time events, but regularly repeated inventories may qualify as monitoring or even become components of a larger monitoring project.

Monitoring can be defined as the collection and analysis of repeated observations or measurements to evaluate changes in condition and/or progress toward an objective. As compared to inventories, monitoring adds the dimension of time. Monitoring often samples the same sites over time. Features of monitoring to note are the repeated observations and measurements (a feature often shared with research), evaluating change(a feature sometimes shared with inventory), and a pre-defined goal or objective (never a feature of either research or inventory). In summary, monitoring is a process of paying attention over time to a specific issue or condition by using repeatable, reliable methods of observation and measurement.

3 Scopes of monitoring- Province- wide, project - level

At the largest scope, or level, the provincial Bureau of Soil and Water Conservation is required to monitor the overall condition and trend of the eco-environment in the province. This province-wide program will track the condition of natural resources and identify threats to them. It will lead to periodic assessments and reports on trends in such items as soil erosion in landform types, areas of grassland, areas of forests and plantations, availability and amount of water, area of desertification, number and type of conservation projects completed, yields of major crops planted, amount and kind of forest products produced, and the status of rare and endangered species of plants and animals. Other items may be included. The province-wide program is a long-term, on-going, permanent activity. It will meet requirements of the law for a periodic report on the state of health of the province's eco-environment, for example a bulletin of soil erosion according to the Law of Soil and Water Conservation.

A smaller scope, or level, of monitoring is the project-level activity intended to evaluate the success of specific projects in meeting their objectives. Project-level monitoring is operational in scope, intended to support the conservations activities and projects of the provincial bureau. Such projects could include conversion of farmland to grassland or forests, check dam construction, trials of plant species, restoring natural forests, intercropping (trees and crops) trials, and new construction techniques. Project-level monitoring is short-term, carried out only as long as is necessary to reach conclusions about the results of the project or activity.

3.1 Project-level monitoring

Project-level monitoring is intended to provide data to be used to evaluate the results of specific practices or projects. The results obtained from this monitoring will aid planning of future projects and will improve the coordination of investments and on-ground efforts in one province. This process will also help provide assurance to the people and leaders that natural resource management efforts are effective and are being managed efficiently.

Monitoring will emphasize relevance and practicality, with appropriate scientific rigor. Measurements are to be relatively more flexible with regard to quantification than monitoring for strictly scientific purposes. In many cases, the degree of quantification required to meet the purposes of environmental management may be relatively low and quantification such as "low- high" or "low- medium- high" may be satisfactory. Cost and speed of measurements may be more important, and useful, than precise measurements.

The purposes of project-level monitoring include:

(1) Evaluating new conservation practices and their potential for wider use in the province.

(2) Evaluating the progress of existing conservation practices in meeting their objectives.

(3) Indicating the need for modifications of conservation practices.

The length of time for monitoring a project may be only months but in most cases the duration of the monitoring will be several years. In the case where it may be desirable to monitor the progress of formation of natural forests, the monitoring will be done for many years. Field data from such longer duration project monitoring should be useful as input to province-wide monitoring. Monitoring the results of grassland establishment will, of course, be much shorter than monitoring forest restoration practices. In both cases, however, the general purpose is the same —— to determine if the test of new species or methods has produced satisfactory results.

Project monitoring, like province-wide monitoring, is a regularly recurring activity. For projects, the selected indicators (see below) should be measured at least annually. Depending on the nature of the project, it may be necessary to monitor some indicators seasonally, monthly, or following each storm event, in order to be able to assign changes in conditions to the proper cause.

3.2 Province-wide monitoring

The purposes of a province-wide monitoring program, while similar in some respects to project-level, also differ from those of project-level monitoring. The major differences are the scale (provincial) and long-term, recurring nature of the program. The purposes of province-wide monitoring include:

(1) Detecting and measuring changes in landform types, land uses, and ecological conditions of natural resources.

(2) Providing information for a permanent database that is useful for reports to meet legal requirements, to provide managerial and fiscal accountability, to give guidance for formulating and revising policies, to support management decisions on allocation of financial resources, and for educational information.

(3) Providing "early-warning" of changes or threats to the eco-environment.

(4) Giving information to support establishing or changing targets for specific resource conditions.

Monitoring natural resources in an area as large and diverse as Shaanxi, for example, is an enormous undertaking. The monitoring methods in north Shaanxi will often be very different from those used in south Shaanxi. In fact, the monitoring programs for these two major areas of the province may best be developed independently of each other in view of the wide differences in ecological conditions, land uses, soils, and climate. The results can be combined, as needed, for reporting.

The frequency of monitoring is the most important factor in determining the total cost of the program. If the monitoring interval is short, the cost of its annual operation will be high, but changes in conditions may be so small as to escape notice. If the interval is long the annual cost is reduced, but the data may be unable to attribute causes and effects to changes in eco-environmental conditions.

An annual inventory, on the scale of a province, is much too ambitious. A very large staff of specialists would be required to collect the data, analyze it, and prepare timely reports. Ten years is not too long an interval for changes in certain factors, such as the slower-growing forests, but it is probably too long to show the more rapid changes in farming practices that may result from new technologies or new policies, or soil erosion resulting from construction projects such as railway and highway construction. An interval of five years appears to be a reasonable compromise of cost, meaningful data, and timely reports. It also coincides with the national planning cycle of five years.

Satellite imagery is a useful and economic approach for such large-scale projects as the province-wide monitoring. Satellite imagery has the advantage of generally lower cost (per km^2, for example) than conventional mapping schemes. In combination with Geographic Information Systems (GIS) they are an excellent approach for assessing large areas and for determining broad changes in conditions.

Satellite information should be combined with field data collected from permanently-installed field plots.

Approaches for monitoring forest health in China have recently been reviewed by Chen et al. 2003. Their paper provides a good overview of ecosystem monitoring and assessing methods. They state three preconditions for assessing ecosystem health: 1) a clear conceptual framework, 2) adequate data sets and, 3) proper research and analysis techniques.

4 Selecting indicators

Selection of indicators to be measured, the spatial sampling design of indicators, and the intervals of measurement, are most important considerations. Additionally, the specific conditions and properties (i.e. "state variables" in ecological terminology) of the eco-environment that are desirable for measurement must be determined. And finally, the levels of the indicator measurements at which they indicate desirable or undesirable conditions must be determined.

(1) Indicators should be ecologically and operationally meaningful, closely related to the important ecosystem processes, functions, and services.

(2) They should be sensitive to environmental disturbances and changes.

(3) They should be simple and easy to measure.

Indicators are the "vital signs" of ecosystem health. Some possible indicators and their measurements in community types are shown in Table 1.

Table1 Possible indicators for eco-environment monitoring

Indicator	Community (Eco-environment) Type			
	Natural forest	Plantation	Grassland	Desert
Species diversity	Trees, shrubs, grass	N/a	Grasses, shrubs	Grasses, shrubs
Biomass	Total	Total	Total	N/a
Soil erosion	% area, severity	% area, severity	% area, severity	% area, severity
Birds	No. species	No. species	No. species	No. species
Non-native species	No., %	No., %	No., %	No., %
Endangered/threatened species	Occurrence	Occurrence	Occurrence	Occurrence
Area of community	hm^2, km^2	hm^2, km^2	hm^2, km^2	hm^2, km^2

These indicators fulfill the above mentioned conditions, which may be further noted as follows:

(1) Species diversity, as measured by one or more diversity indexes, indicates a change in the community towards a more complex, possibly more stable, community. In general as plant succession proceeds towards more natural forests and grasslands, species diversity will be expected to increase.

(2) Biomass accumulation is a direct measure of changes in the primary productivity of the community.

(3) Erosion could be estimated from hillside erosion plots or from ocular estimates of the degree of sheet, rill, and gully erosion on fixed observations areas.

(4) Birds indirectly indicate changes in plant diversity as well as indicators of seed dispersal in some plant species.

(5) In general, a decline in the number and frequency of non-native species would be a desirable indication of the community's movement towards a natural state.

(6) In areas where such species occur, or where habitat exists for them, an increase in their numbers and frequency would indicate a desirable change of the community.

(7) Positive changes in area of natural forests and grasslands would be considered desirable. Negative changes in area of desert would be desirable. Area changes track the overall progress of environmental improvement and management efforts towards area goals. This information could be effectively taken from satellite images. The frequency of observation would be much longer than for the other indicators.

Measurement of the above indicators, whether from field plots or remotely sensed, is straight-forward using developed methodologies described in the ecological literature and in GIS procedures.

5 Sampling design

Monitoring data must be collected in a scientifically credible manner so that they will withstand scrutiny from critics and so they can be used to address current and future management issues. Sample sizes will almost always be limited by shortages of funds and personnel, so it is important to be able to make inferences to larger areas from data collected at relatively few sample locations. This will not be the problem for project-level sampling as it will be for the province-wide program.

Sampling design for the provincial program is complicated not only by the ecological and geographic diversity of the province, but also by the fact that the Bureau is interested in an "omnibus" program with many goals. The provincial program will want to know the status or trend of a number of various natural resources rather than answering a single, focused question.

Sampling design is the realm of statisticians, but some preliminary ideas are presented here, with particular reference to province-wide sampling.

(1) Probability sampling is the preferred statistical approach for such large areas as different parts of a province, take an instance, north and south for Shaanxi. In this approach, the areas are overlaid with a grid network such that every area in the province is included in one, and only one, sampling unit (grid square). The grid is the sampling framework, not the sample itself. The grid is the list of all possible samples from which the actual samples will be selected.

A sampling design is used to probabilistically select units. Constrictions may be placed on the design such that each county, or other political area, must be assigned a minimum number of samples. Probability samples occur when each unit of the province has a known, non-zero probability of being included in the sample, and always include a random component (such as a systematic sample with a random start). The credibility of data that are not collected using these principles is easily undermined.

(2) Areas that are too remote, too unsafe, or too difficult to sample are excluded from the program. However, the provincial program will be unable to make inferences about the resources in such areas.

(3) "Judgment" sampling, using "representative" areas selected by experts or politicians, should be avoided. Judgment sampling sounds good when there are no controversies concerning the program, but so-called "representative" sites will come back to haunt the program in the future when such sites will be discredited by critics and may also give biased, unreliable data.

(4) In contradiction to judgment sampling, there may be legitimate, generally recognized areas of special interest where it is desirable to have a more intensive sampling scheme. Special interest areas could include high-risk watersheds, flood-prone areas, or areas where conservation practices have been intensified. Statisticians can include such considerations in the probabilistic sampling design by using unequal probability sampling.

(5) Permanent plots that are revisited over time are the recommend approach for on-the-ground data collection. Revisiting the same plots removes plot-to-plot differences from the change estimates, thereby increasing the precision of the design.

(6) The number of samples is a very important aspect in monitoring designing. Too few samples, while appearing to be a cost-saving measure, may increase the errors of management decisions when important changes are missed or detected too late for management to be effective. Too many samples will waste time and money.

The sample size that is needed to meet a sampling objective is largely a function of the effect size, which is the amount of change in the resource from time to time that the manager seeks to detect, and the variability of the resource across space and time. The manager must tell the statistician how much change they want to detect, and with what certainty.

(7) The final design will consist of a combination of on-the-ground data and remotely (satellite) sensed data. The ground plots and the satellite plots may be collocated or there may be separate sampling schemes for each approach. Collocation, at least of a portion of the plots has the advantage of providing more total information on the plot that if only satellite or only ground information were available at that point.

The actual process of designing a sampling scheme is not easy and will require personnel with GIS, statistical, and ecological experience. The important initial step is to determine the goals and objectives of the sampling efforts, because without clear objectives, little progress can be made in designing efficient monitoring programs (see further comments below).

6 Documentation

Both project-level and province-level monitoring programs must be fully documented as to methods and procedures. Project-level documents will be less demanding in terms of needed documentation. Their format may be the

usual "Introduction, Methods, Materials" of a research proposal. Upon completion, the project monitoring results should be reported in much the same way as are research results.

The province-level document must be exhaustive in its treatment of objectives, purposes, design, analysis, reporting, and personnel qualifications. A suggested outline for this document is included as Fig. 1.

Photo point monitoring is a useful method for monitoring changes in vegetation and soil by using repeat photography. It involves repeat photography using digital or film cameras that are precisely located and controlled so as to permanently record visual documentation of conditions on the ground. It should be a component of all project and provincial monitoring The publication by Hall (2001) is a complete and detailed handbook on using photo point monitoring for ecological purposes.

The most important part of the early process is describing goals and purposes. This requires input from province leaders, university and government scientists and technicians, county and prefecture leaders, farmers, and others interested in the province's natural resources.

Suggested Content for the Environmental Monitoing Program Documentation

Background and Objectives
- Background/history, describe resource issues being addressed
- Measurable objectives for the program
- Sampling Design

Overview of the design, including rationale for selecting this sampling design
- Procedures for selecting sampling locations; stratification, spatial design
- Sampling Frequency and Replication
- Recommended number and location of sampling sites
- Recommended frequency and timing of sampling
- Level of change that can be detected for the amount/type of sampling being instituted

Field Methods
- Field season preparations and equipment setups (including needed permits)
- Sequence of events during field season
- Details of taking measurements, with example field forms
- Post-collection processing of samples
- End-of-season procedures

Data Handling, Analysis and Reporting
- Overview of database design
- Data entry, verification and editing
- Recommendations for data summaries and statistical analyses to detect change
- Recommended report format with examples of summary tables an figures
- Recommened methods for long-term trend analysis (e.g, every 5 or 10 years)
- Data archival procedures
- Location and protection of photo point data

Personnel Requirements and Training
- Roles and responsibilities
- Qualifications
- Training procedures

Operational Requirements
- Annual workload and field schedule
- Facility and equipment needs
- Startup costs and budget considerations

References

Figure 1 Outline of documentation of the eco-environment monitoring program

7 Implementing the program

Monitoring a province's eco-environment is an enormous task that will require a lot of collaboration among specialists and cooperation with various agencies. The program will require a significant amount of personnel and fiscal resources in order to carry on the maintenance of the monitoring databases, data security and verification, analysis and synthesis of data, and training and supervision of field personnel.

Implementing the monitoring program for the first time is a complicated process of assembling qualified personnel for the monitoring team, evaluating available data so as to reduce duplication of efforts, developing and field testing methods of collecting remote sensed information and field data, maintaining quality control, and analysis and syntheses. An outline of this process is presented as Figure 2.

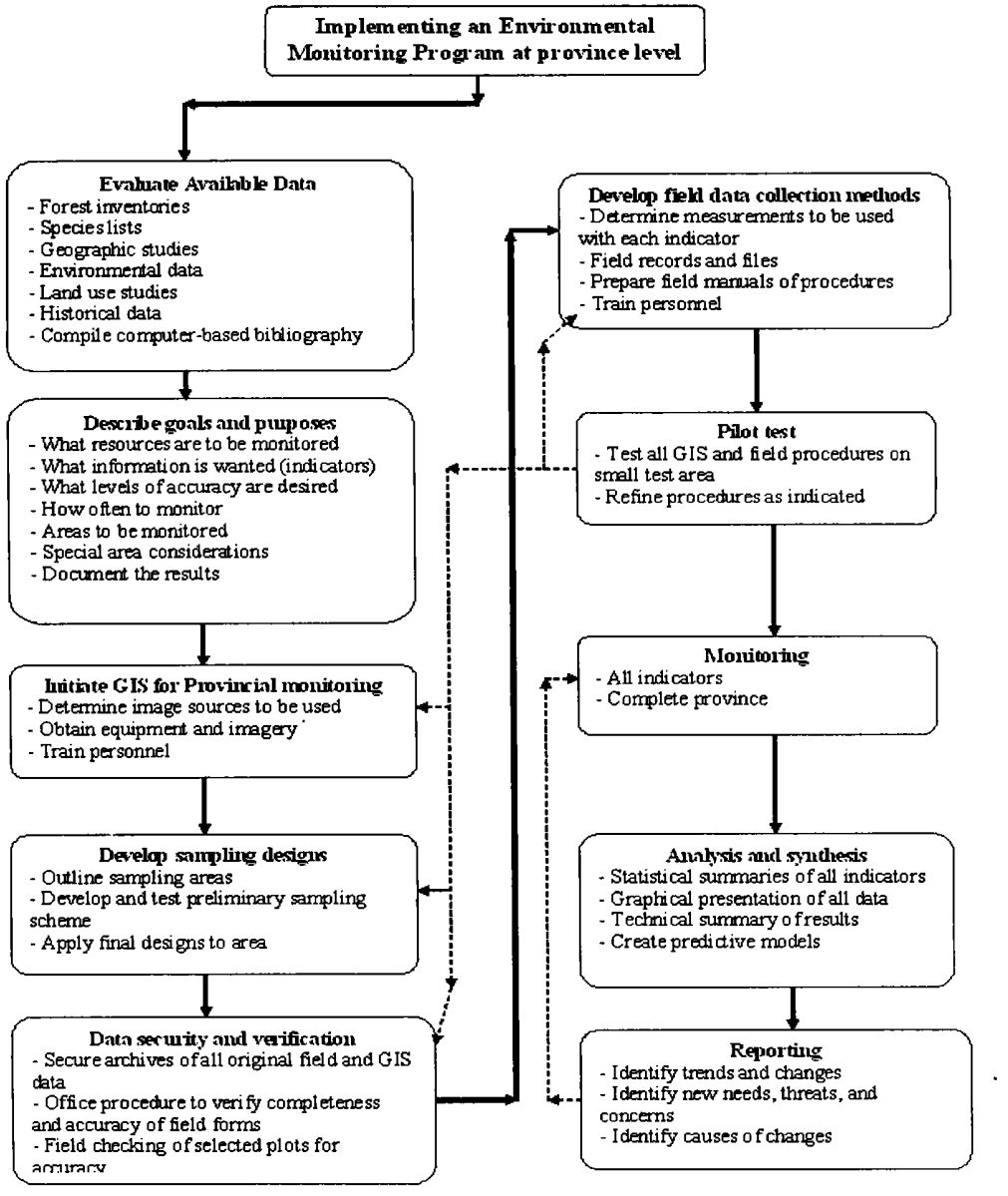

Figure 2 Outline of implementing the monitoring program

A first step in describing goals and purposes would be a conference of invited participants. The purpose of the conference would be to present the legal requirements of the monitoring program, and outline a general process for developing the program. Speakers could be asked to prepare papers for the program on specific aspects of large monitoring programs that could be considered by the Bureau. As a final part of the conference, participants could be asked to rate, or rank, their own interests in content areas and purposes of the monitoring program. Published proceedings of the conference would document the presentations and the findings of the conference. Some of the activities in the process (Figure 2) can occur simultaneously. Evaluation of available data could begin immediately and perhaps be accomplished in conjunction with a university where library resources are available and some literature databases already exist. Initiating the GIS could begin immediately.

Most other aspects of implementation cannot begin until goals and purposes are described and agreed upon. This points out the importance of accomplishing the goals and purposes component early on.

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