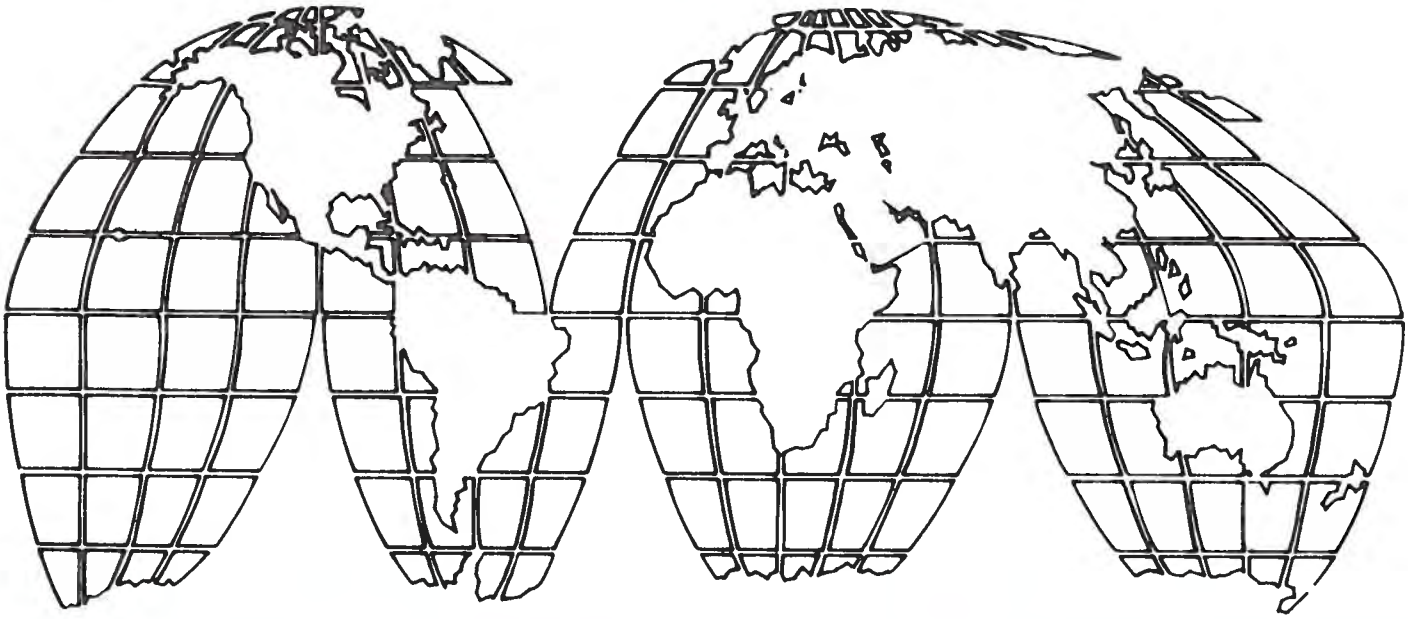
A.I.D. Program Design and Evaluation Methodology Report No. 14

Preliminary Indicators for Monitoring Changes in the Natural Resource Base



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PRELIMINARY INDICATORS FOR MONITORING CHANGES IN THE NATURAL RESOURCE BASE

A.I.D. PROGRAM DESIGN EVALUATION METHODOLOGY NO. 14

by

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The views and interpretations expressed in this report are those of the author and should not be attributed to the Agency for International Development.

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PREFACE

This report has been prepared for the Agency for International Development, Bureau for Program and Policy Coordination (A.I.D./PPC) under contract No. PDC-0085- 0-00-9054-00, dated June 28, 1989.

This paper describes 10 simple, practical indicators and suggests ways in which they can assist A.I.D. field personnel to monitor both the positive and negative impacts of project interventions on natural resources--that is, soils, water, natural vegetation, and wildlife. It also discusses methods for collecting and using the indicators, stressing reliance on locally available information and simple techniques. Furthermore, the paper contains a brief discussion on indicators for measuring impacts on areas of historical, religious, cultural, and scientific significance.

Although the main thrust of the paper deals with identifying impacts at project output and objective levels, it also touches on how indicators can eventually be used to measure longer range impacts of USAID Mission programs, particularly from dealing with ARD (agricultural and rural development).

GLOSSARY

A.I.D. - Agency for International Development

ARD - Agricultural and Rural Development

CDIE - Center for Development Information and Evaluation

FAO - Food and Agricultural Organization

GIS - Geographic Information System

ICRAF - International Council for Research in Agroforestry

ILCA - International Livestock Center for Africa

IUCN - International Union for the Conservation of Nature

PIRT - Projet Inventaire Resource Terrestre

S&T - A.I.D. Bureau for Science and Technology

OICD - Organization of International Cooperation Development

USDA - U.S. Department of Agriculture

WWF - World Wide Fund for Nature

1. INTRODUCTION

Most agricultural and rural development (ARD) activities are undertaken to improve the lives of rural people. Almost all ARD efforts, either directly or indirectly, aim at increasing crop or livestock productivity, which implies a more intensive use of the natural resources--land, vegetation, water, and wildlife--available in an area. Therefore, it must be assumed that funding any ARD activity risks increasing pressure on the natural resource base, unless special precautions are taken.

Most ARD interventions are liable to have both positive and negative impacts on the physical environment. These impacts can be significant or minimal, immediate or long term--that is, not noticeable until several years after the interventions have been completed.

Among ARD activities, some are more likely to affect natural resources than others. In particular, projects that change large land surfaces (e.g., massive earth moving, land leveling, and benching), where existing vegetative ground cover is removed or changed drastically or where existing water courses (or aquifers) are altered, are apt to produce significant impacts. Even projects that do not affect an area's land or vegetation directly may indirectly cause all kinds of adverse effects. For example, a farm credit program may not seem to affect an area's natural resources. Yet, if farmers use the money to rent tractors to plow their land, the indirect unanticipated result may be increasing soil erosion in the fields. Before tractors were used, soil losses were minimal because the land was plowed and cultivated more discriminatively.

A strong argument can be made that regardless of how successful rural development projects may be, if as a result of the interventions any part of the natural resource base has been reduced or destroyed, the rural people whom the project intended to help will ultimately be worse off. That is why concerns for environmental safeguards in development work are making steady, but slow inroads into the way public funding agencies like A.I.D. plan and carry out rural development projects. Development agencies are looking more closely at what can be done to improve the monitoring and evaluation systems of projects in the rural sector.

Indicators and methodologies to observe and measure changes in an area's or a country's natural resource base are neither new nor lacking. A scan of the pertinent literature reveals that different organizations, under different circumstances, use a wide assortment of indicators. Most of these are very sophisticated, and their use frequently requires technical expertise and

costly investments in data collection and analysis. Therefore, they are often impractical for use at project level.

1.1 Purpose of this Paper

This paper offers an alternative to project managers who have limited resources to invest in sophisticated data collection systems. It proposes indicators that can be set up using fairly simple and low-cost data collection methods. They can provide a set of indicators that provide preliminary answers to questions about a project's impact on natural resources and indicate when further investigation by experts might be required.

1.2 Selection of Indicators

The proposed indicators were selected on the basis of the following criteria:

- They should provide tangible, easily measurable data about changes that occur in soils, water, natural vegetation, and wildlife.
- They should be applicable over a range of different ecosystems, from deserts and highlands to the humid tropics, wetlands, and coastal areas.
- Data collection should not be too difficult, too costly or time-consuming.
- They should primarily address project-level concerns, rather than programmatic, regional, or countrywide concerns.
- Where feasible, local people should be able to assist in data collection. Therefore, they should focus on practical aspects, be straightforward and deal with issues meaningful to rural people.

In their most basic form, the natural resources (the biophysical environment) available to rural people are land (soil), water, and vegetation (e.g., trees, shrubs, grasses, and other ground cover). It therefore makes sense, indeed seems mandatory, that each of these three elements be monitored for changes. It also implies that separate indicators are needed for each.

In many instances, a fourth category, wildlife (animals and fish), needs to be added. In special circumstances, a fifth element, areas of scientific, historical, cultural, religious, recreational, or scenic significance, may also have to be included for complete assessment of project impacts.

Although specific indicators for each of these categories can now be identified, the task of selecting only those that comply with the specifications mentioned in Section 2 is somewhat difficult, for the following reasons:

-- Great variations exist between different project areas; geographic diversity between project sites makes standardization difficult.

-- Because of differences in the historical and cultural characteristics of people in different rural areas, resource-use patterns vary considerably from group to group, from one population to the next. In addition, a myriad of different administrative/political government systems are in force in different countries.

-- Some A.I.D. projects are large and may cover entire sectors, while others are more modest and specific to a location or an activity.

-- The nature of different projects can vary greatly, for example, from projects that support closely targeted soil conservation interventions, to those that support broader programs aimed at strengthening local agricultural extension or research capabilities.

In most cases, every element of the natural resource base need not be monitored. The effort would be unmanageably extensive, and much of the information gathered would be of little use for highlighting the resource changes of importance at a given site.

What is useful if more complete coverage is ultimately required is to divide the various indicators into quick-check primary indicators and secondary indicators, for more in-depth information on specific subjects or issues. Then, if the primary indicators do not indicate any problems or special concerns, more in-depth observations are not needed. But if one or more of the indicators bring to light something abnormal, secondary indicators may be used to uncover the underlying issues and causes. At this point, more sophisticated indicators requiring additional (and often more costly) measurements or observations should be used.

Thus, indicators can be grouped according to need. In this paper, special attention is given to primary indicators. The secondary indicators, shown in Table 1, are mentioned in order to point to additional tests, observations, and so on that may be needed in the field.

On this basis, the five key elements--water, soil, vegetation, wildlife, and unique areas--and their basic indicators can now be defined and described more fully. The following section explains which particular characteristics can be measured or observed.

2. INDICATORS FOR MEASURING CHANGES IN THE NATURAL RESOURCE BASE

2.1 Water Quantity and Quality

The quantity and quality of water from sources in a project area (rivers, streams, lakes, wells, etc.) can be negatively affected by agricultural development activities such as irrigation works, forest clearing and inappropriate farming practices and crops. Therefore, it is imperative that measures be taken to monitor factors that will affect the condition of water sources. The most important indicators of impact on the quality of water are changes in stream flow, storage or drainage patterns; while changes in the quality of water can be detected by monitoring the physical, chemical and biological properties of the water. Section 3.1 describes simple methods to monitor such changes.

2.2 Soil Erosion and Productivity

The important indicators for measuring impacts on soils are wind and water erosion and trends in soil productivity, particularly in traditional farm fields. Most existing environmental impact evaluation procedures address these points in one form or another. But they become even more important when the opinions and perceptions of local farmers or pastoralists are included in these evaluation efforts. Most rural people (except pastoralists and hunter/gatherers) are directly, and almost completely, dependent on the food crops they raise on their land. If soils "give out" for whatever reason, the farmers' most important resource base, and with it, their livelihood, is in serious jeopardy. Moreover, knowledge about the trends in soil fertility can help farmers adjust their cropping and cultivation practices.

Table 1. Resource Change Indicators

Indicator	Primary Indicator	Secondary Indicator	Type of Data Needed
Water			
Quantity	X		Stream flow, water tables, natural storage and drainage patterns.
Quality	X		Chemical, physical and biologic properties.
Reliability		X	Seasonal and annual highs and lows. Availability of alternative sources.
Accessibility		X	Access rights and conflicts.
Soil			
Erosion	X		By wind or water topsoil losses. Gully-, channel- or bank erosion.
Productivity	X		Chemical and physical soil properties. Also: Yields (crop, range, wood, etc.).
Land Availability, Suitability		X	Percent of needs satisfied. Percent of submarginal land cultivated.
Fallow periods		X	Adequacy of fallow length.
Vegetation			
Permanent vegetation ratio	X		Ratio of areas with permanent vegetation over open or cropped areas.
Natural veget. composition, density	X		Species composition and densities.
Open areas	X		Tree/shrub cover percentage in landscape.
Productivity		X	Yields (including secondary products).
Other		X	Habitats, species diversity, etc. Also: Access and local control.
Wildlife			
Population	X		Number of species, densities.
Habitat	X		Extent (size, area) and quality.
Other			
Unique areas	X		Depends on location and nature of object. Can be geologic, historic, sacred areas, archaeologic, species diversity, etc.

Section 3.2 discusses methods for detecting soil erosion and productivity.

2.3 Vegetation

Three indicators are of basic importance for monitoring changes in natural vegetation: (1) changes in the relative coverage or presence of natural vegetation (expressed in surface area) in relation to adjoining open or farmland areas, (2) on land covered by natural vegetation changes in the composition and density of the vegetation, and (3) on farmland or open areas the changes in the tree- and shrub-cover percentage.

If the data show that the ratio of areas covered by natural vegetation is changing, that plant density and composition of natural vegetation have begun to change or if the tree cover percentage has changed on farmland, it means that the protective role natural vegetation plays will also have changed. It also means that in all likelihood, such factors as wood yields, pasture conditions, or wildlife habitats are being affected as well. If the data show severe deterioration, more in-depth analysis using secondary indicators (shown on Table 1) may be called for.

2.4 Wildlife

The main indicators for measuring impacts on wildlife are as follows:

- -- Number of species and size of population of animals, including fish and game species. (This indicator is similar to the composition and density indicator described in Section 3.3.)

- -- Extent and quality of habitat. Extent and quality of habitat can also be used as secondary indicators because they depend almost directly on the indicators mentioned above. Abundance of, or changes in, the number and population of non-game species is another secondary indicator.

Monitoring the two secondary indicators may provide important clues to ecologic changes that otherwise may not be apparent. In most instances, however, the primary indicators are sufficient.

2.5 Unique Areas

Areas of particular scientific, cultural, historical, religious, recreational, or scenic importance deserve monitoring. These areas may be of significance to local people, who may have their own list of what is important to them--burial grounds or sacred forests--or they may be of importance to the international scientific community--sites of geological significance or species diversity, for example.

2.6 Indicator Summary

Table 1 lists the primary indicators discussed in the paper and summarizes the type of data each requires. Another column can be added to the table to indicate likely impacts for proposed interventions or project impacts in case of ex post evaluations.

3. HOW TO COLLECT AND USE INDICATOR DATA

3.1 Water Quantity

What and how to Measure

Stream flow, storage, and drainage are important factors to measure when monitoring changes in water quantity. Water level (water height) or, in the case of groundwater, distance (depth) to the water table should be measured at different times during a year and compared with similar measures taken in previous years.

Water levels can be measured with a gauge placed along a stream or lake bank.[1] At different times during the year, pre-

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[1]A gauge can be made out of sticks or poles of wood. A metal gauge (pipe, rod, small channel or angle steel sections, preferably galvanized) also can be used and is more durable. After it has been firmly placed vertically (use string and rock to verify), it then can be painted. Two different colors (frequently red and white) are used and applied in 10 cm wide bands. It should be long enough to stick out above the water line during extreme floods and be placed along the bank at a point that is permanently below the water surface even at low flow. In intermittent streams, this means it should be installed at the lowest point in the channel.

ferably when the water levels are high, again when they are low and immediately after a rainfall, water marks left on the gauge should be read and recorded. To avoid the possibility of people or livestock disturbing the gauge or flood waters overtopping or washing it out, a permanent benchmark can be built out of the reach of extreme flood peaks. If the benchmark is placed high, water levels will have to be measured by differential leveling, as shown in Figure 1. This technique may also solve the problem of reaching the gauge during high water levels.

Sometimes a lake or reservoir bank is so flat that the gauge must be placed far out into the water to record water levels during low water stages. Unfortunately this means that the gauge will be surrounded by water during high water levels and thus difficult to read from the bank. A permanent benchmark can be used instead as in the example above or a boat must be used to reach the gauge.

Groundwater levels (or distance from the ground to the groundwater table) can be measured with a string lowered through the opening of a well. Although better equipped technical agencies use more sophisticated techniques for measuring groundwater levels, the technique suggested here is simple and provides useful, relatively accurate data.

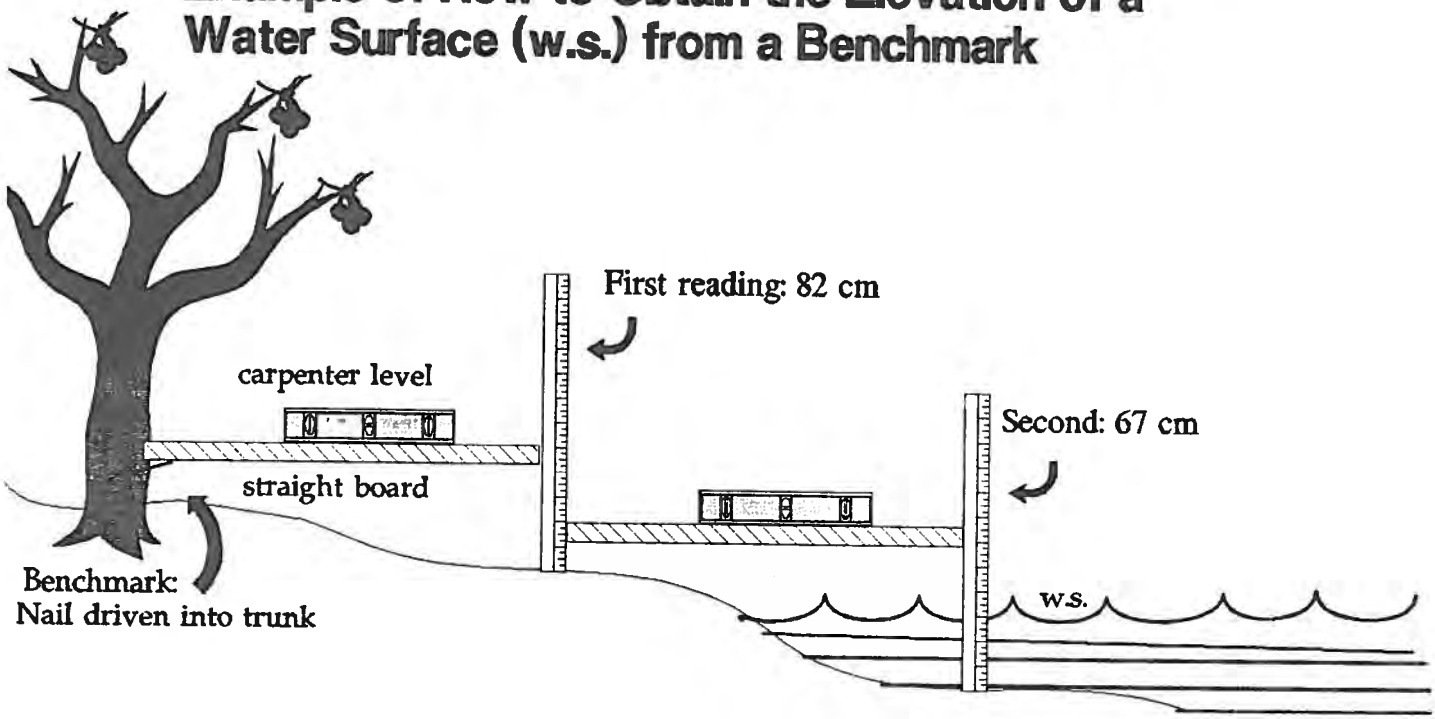
When to Measure Water Quantity

For monitoring changes in both surface water and groundwater, records of water levels at extreme high and low stages are important. But during normal periods, one reading every 3 months is sufficient. In the case of streams or rivers, flood peaks often occur when no one is monitoring the gauge. At such times, flood water levels can be reconstructed by looking for recent high water marks along the banks and comparing gauge readings taken of these with previous ones measured before the flood.

Interpretation of Data

Impacts are obvious where water has been diverted (change of natural drainage pattern) or natural flows have been drastically disturbed: water simply no longer flows the way it used to. In such cases, a definite overall statement to this effect is all that is necessary to record the change. This initial finding may signal the need for further investigation through the use of secondary indicators. But where changes are more subtle and indirect, impacts are more difficult to document. Cause and effect relationships are not immediately evident.

Figure 1
Example of How to Obtain the Elevation of a Water Surface (w.s.) from a Benchmark



Water Surface Elevation:

Top of Nail:	**200.00 m**	
minus first reading:	**- 0.82**	**(assumed and held constant)**
minus second reading:	**- 0.67**	
	198.51 m = w.s. Elevation	

The gauge technique proposed in this paper primarily indicates how much runoff has been produced by rains which fell during recent months. Human- or project-induced change, which also may affect stream flow but may become evident only in the long term, are difficult to detect without records that stretch over several years, preferably 5 to 10 seasons before project activities began.

Indirect or subtle changes in water flow or water recharge patterns have to be documented by comparing and combining recent measurements and other monitoring data with carefully collected statements from local residents. However, a certain bias in the opinions or perceptions of local residents must be considered especially if local people may have been adversely affected by the change, however inadvertently. Host country technical agencies may be able to help interpret the data. Where changes have produced unfavorable results, special studies by experienced people may be needed.

Required Inputs

Installing a gauge requires a small project crew for 1 day per location. Subsequent routine readings should not take more than half an hour per visit, including time needed to look around, do basic maintenance, and talk to some of the local people. In many cases, a local person can be found to take the measurements and record them on simple forms provided by the project. The only other effort required is to make occasional visits, collect the data, provide additional materials, and, depending on the installation, provide some training.

Limitations of Gauge Observations

Gauges only measure water height (stage) and water depth to groundwater table. To measure flows and yields, the flow characteristics of channel cross sections[2] have to be evaluated (slope, area, roughness) so that stage discharge tables[3] can be developed and used. This effort requires the services of a hydrologist for several days and some sophisticated equipment (e.g., survey

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[2]A diagram showing the groundline of a depression through which water naturally flows, cut at right angles to the direction in which water is flowing.

[3]A table which relates the depth of water in a stream or river with the volume of flow occurring at that stage.

instruments, velocity meters, and, for larger streams, temporary installation of a cable suspension system).

Despite the limitation of simple gauge observations, they can provide preliminary data on changes in water levels over time. If the data show a sharp drop in water levels when compared with data from previous years (even if the observation period covers only a few years), rapid changes may be taking place, requiring further investigation.

Long-Term Values of Stage Records

Stage records[4] can serve as valuable long-term points of reference--a "historical" perspective when more sophisticated measurements are taken later. Such records also provide a resource-base for local people to exchange information; their knowledge of the area can thus be better tapped and their experience more easily factored into an overall assessment of the situation.

3.2 Water Quality

What to Measure

The prevalence of water-related diseases such as malaria, bilharzia, and diarrhea in the local population is a good indicator of the quality of water in an area. Information about disease prevalence can be gathered by querying local people and health workers. If incidences of water-related diseases are reported, water sources must be tested and analyzed in a laboratory according to standard procedures. Since these may vary depending on the seasons, all sources of water should be checked. If the development project includes use of agricultural chemicals, water samples should be checked for traces of these compounds as well. For advice on how to take water samples properly, the World Health Organization or A.I.D.'s centrally funded "WASH" (water and sanitation for health) project can be of assistance. The following publications may be of help: A.I.D. (1982), Safe Water and Waste Disposal for Rural Health: A Program Guide, and WHO (1958), International Standards for Drinking Water, Geneva.

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[4]A tabular compilation of water depths (or heights) over the course of time (daily, monthly and annually).

When to Measure

Water samples should be taken during low stages, dry periods, and the rainy season. Water samples during the rainy season are necessary in part because distribution systems (pipes) often get contaminated during periods of heavy rain, when the ground is saturated.

Interpretation of Test Results

Test results must be compared with minimum standards for safe drinking water. In particular, test results must assess especially the biological and chemical quality of water. The resulting data will reflect any project-induced changes that occur.

Required Inputs

Three water samples per year (three trips for one project staff[5] to the site per year), including complete laboratory test (up to $150 per sample), are adequate for measuring water quality at one specific spot or location.

Long-Term Value of Water Quality Tests

Apart from revealing changes in water quality during a project's life, test results may serve as reference points for more detailed studies carried out later. Depending on the nature of a project, a delayed adverse impact on people's water sources is possible.

3.3 Soil Erosion

What and How to Measure

The primary indicator for assessing project impacts on erosion is topsoil loss. In severe cases of soil erosion, roots of trees and shrubs begin to appear above the ground, visible evidence that topsoil layers have disappeared.

One method for measuring soil loss is to drive a gauge (preferably metal) into the ground, periodically checking the ground

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[5]No specialist is required for this task.

surface around the gauge for changes in the soil level (as measured against the graduated scale on the gauge). If surface soil has gradually, but noticeably, eroded, erosion rates are in the catastrophic range. Even if the problem is less severe--that is, the change is hardly noticeable even after careful observation over a period of years--soil loss may still be at a dangerous level, far above what may be acceptable.

Another way to measure soil loss is to install "soil traps." Two types are suggested: Horizontal pits can be dug 2 ft x 2 ft x 6 ft, with the long dimension running parallel to the contour lines of the slope. The bottom of the pit is lined with boards or made smooth and firm with soil cement or, though less practical, a strong sheet of plastic to hold the mud and dirt that flows into the pit each time it rains. After each runoff, the soil, gravel, or sand accumulated at the bottom of the trap must be carefully lifted out and measured (e.g., number of filled shovels, scoops, or buckets).

A second, less elaborate method for measuring soil loss consists of placing wooden boards horizontally across a slope at the bottom of a field where soil loss is to be determined (see Figure 2). The amount of dirt piled up against the boards[6] after each rain is then measured (normally by volume not by weight).

It must be clearly understood that all these methods give relative values, not quantitative measures of soil losses. For more accurate assessments (on the level of secondary indicators, perhaps), standard run-off plots will have to be constructed and properly maintained.

When and Where to Measure

Soil losses have to be measured after each rain that causes surface runoff. Debris must be cleared from the traps in time for the next rain. Measurements are most important during the cropping season, especially when fields are relatively bare and much of the freshly prepared soil surface is not yet covered by crops or vegetation.

The soil pits or horizontal boards are particularly useful when they are installed in pairs, next to each other, as shown for pits in Figure 2. In this way, runoff from treated fields (e.g., fields that have been benched or ridged or where contour

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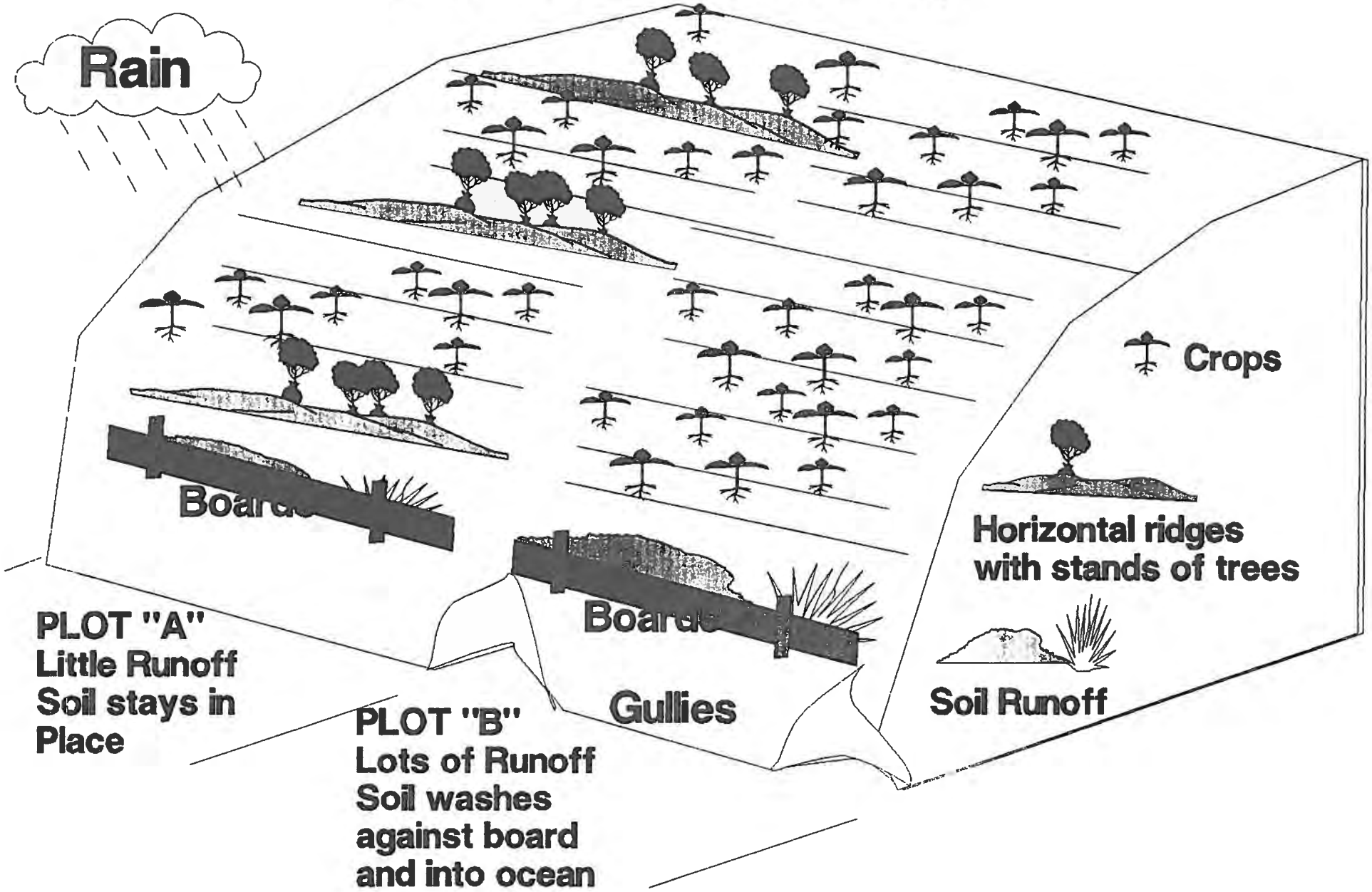
[6]Boards are cheaper and easier to use, but they deteriorate rapidly and may disappear. Pits take more time to install and maintain but obviously last longer and cannot be stolen.

Figure 2.
A "WITH-WITHOUT" COMPARISON
PLOT - PAIR (to measure soil loss)



farming is practiced) can be compared with runoff from untreated fields (e.g., fields that are farmed straight up and down the slope). For the comparison to be valid, the two plots must be managed the same way: same crops, same seeding dates, same weeding and hoeing patterns, and so on. Otherwise, it is not possible to determine whether variations in runoff have been caused by differences in management practices, or by project-induced conservation interventions. Some people may want to compare soil losses on such sample plots before and after treatment, instead of installing traps (either 2 pits or 2 boards) in pairs. The difficulty with this, however, is that much longer periods of record (over ten years) need to be observed for each condition in order to eliminate the influence of variations of rainfall from one storm to the next. Pairs automatically do this as rainfall on adjacent plots is normally uniform enough so differences in the amounts of soil washed away are due to the different treatments only, regardless of how much or how hard it rained.

The study sites must be chosen carefully so that there is little, preferably no, runoff entering the catchment areas from either above or the sides of the plots because this too would greatly distort the results.

Interpretation of Data

When pits or boards are installed in pairs on adjacent treated and untreated plots, as shown for the case of boards in Figure 2, people--including local farmers--can compare the amounts of soil washed into the traps, and are able to determine the relative effectiveness of the different conservation techniques.

Required Inputs

Building soil traps requires some supervision, a small crew, a plan with some basic specifications, some tools and stakes and lumber (preferably treated or painted). Most important, because construction must follow contour lines, some basic leveling equipment will also be needed (a carpenter level or a hand level will do).

Local people can be trained to check the traps and record the data and their observations, but they will need follow-up supervision. If neighboring farmers have offered one of their fields for a test site, chances are they will understand the work involved and be interested in the results of the effort, particularly once they see the difference between the treatments. Still, proper observation requires supervision, time, and travel.

It is of no use to provide the installation and then neglect to follow up.

The indicators described above are useful for discrete areas. However, if investigators require an evaluation of erosion in an entire watershed area, the baseline data can be easily obtained by measuring the sediment (rocks, gravel, sand, silt, clay) that is being transported either suspended in the water or tumbling along the bottom of a stream or river leading out of the area. A composite result is thus measured, not just erosion or soil losses in a number of selected, small farm field plots.

Limitations of the Soil Erosion Indicators

As pointed out earlier, observations based on the soil erosion indicators proposed in this section lack scientific accuracy because external factors cannot be sufficiently controlled during measurements. To get more accurate data on soil erosion, standard "Wischmeier" runoff plots are needed, which are much more expensive to build and maintain.

If more accurate data are needed, Missions and project personnel can get assistance from specialized agencies that deal with soil conservation and erosion control. Agricultural ministries often have such agencies or offices. Local universities, agricultural research stations, or other donor projects involved in measuring soil losses nearby may also be of assistance. In the United States, the U.S. Department of Agriculture (USDA), especially its Soil Conservation Service, Forest Service or USDA's Office of International Cooperation and Development (OICD) and the Forest Service/Forestry Support Program, can provide additional sources of information. Another useful reference is an FAO publication, FAO (reprint 1978), Soil Erosion by Water. FAO Land and Water Development Series No. 7. Rome.

Long-Term Values of the Soil Erosion Indicators

If the above procedures for measuring soil erosion are carried out over a 5- or 10-year period, the data produced can give some indication of long-term soil erosion.

3.4 Soil Productivity

What and How to Measure

The most direct answer to the question "What should be measured to assess impacts on soil productivity?" is yields. But measuring yields is difficult because farmers frequently practice intercropping.

For more in-depth analysis, soil samples can be taken periodically, from representative sites in farm fields for laboratory analysis. At a minimum, such analyses should cover pH, organic content and basic nutrient levels. Additional properties--for example infiltration rate, salinity levels, soil-moisture tension, and toxicity--may also be of interest in specific cases.

However, test results can be no better than the samples taken. At a minimum, pits have to be dug and individual samples taken at different levels (layers), 5 to 15 inches apart, depending on the soil profile.

The problem of measuring yields can be resolved by establishing sample plots, where everything harvested is weighed or measured, (even plant residue such as straw, forage and fuel). As with soil traps a rough measure can be obtained by comparing yields of adjoining plots, where one plot has had some treatment while the other has not (control). A drawback to this method is that it requires tedious work and quality control.

Another, more indirect, approach is to observe visible changes in the structure (size, shape and consistency of soil particles) and organic content of the soils in question. This can be done through visual inspection of the soil particles and "feeling" handfuls of the soil. Poor soils tend to contain a lot of loose sand or heavy clay. When handled, dry, sandy soils will easily run through one's fingers, while moist, clayey soils will stick together like dough. Most soils will fall somewhere in between, depending on the texture (i.e., proportion and distribution of soil particles) of the sand or clay particles and the organic matter they contain. A "good", fertile soil containing an adequate proportion of organic matter normally has a crumbly or loamy consistency, (i.e., it feels loose but is neither "runny" like sand nor dense like clay). Organic matter in sandy soil helps to bind the soil particles, thus giving it a spongy feel. In clayey soil, the organic matter will help to loosen the clay particles, thus reducing their stickiness. In short, field inspection of soil quality revolves around such questions as "Does the soil feel or look loose?", "Is it dense and firm?" or "Is it crumbly and spongy?". Effective soil management can

change soil structure in a few years, i.e., sandy or clayey soils becoming more crumbly and loamy over time.

Where possible, a laboratory analysis of soil samples taken periodically could yield basic information to assess soil quality: the pH, organic content and nutrient levels. A more sophisticated analysis could indicate other properties such as infiltration rate, salinity, water holding capacity and toxicity. The soil sample should be taken from representative sites in farm fields. It should be noted that test results can be no better than the samples taken. At a minimum, pits have to be dug and individual samples taken at different depths, (which, depending on the soil profile, can vary between 5 to 15 inches apart).

Procedures to determine soil texture and structure in the field have been standardized for a long time. The same holds true for field analysis of organic content, consistency,, etc. They are described in numerous text books. One of the most widely used is the classic Soil Survey Manual of USDA (1951), Handbook 18.

Project personnel can use such texts or extension publications to identify basic soil problems in their project areas. In many instances, a basic soils map of the project area--for example, one published by the Food and Agriculture Organization (FAO)--may be available. Host country technical agencies and research stations are also likely to have useful information.

When to Measure Yields

Ordinarily, soil productivity measurement through soil sampling is done once a year. But if crop yield is being monitored, observations should span the entire harvest period. Where there are two rainy seasons a year, measuring may continue year round.

Significant changes in soil productivity take time to develop. In most cases, data-collection must be carried out every 2 to 5 years before trends can be observed.

Interpretation of Yields and Soil Productivity Data

Generally the higher the yields, the more productive is the soil. However, for project benefits to be sustainable, yields must remain high over an extended period of time.

Soil-productivity data should be analyzed by agronomists or soil scientists. Changes in test results over time indicate the direction of trends in soil productivity. Some basic guidelines

for assessing soil-productivity trends are as follows: a relatively high organic content is preferable over one that is low, soil structure should be crumbly, and nutrient levels should be on the increase. Standard texts on soils can provide additional guidelines. One example is Brady, Nyle. (1974) 8th edition. "The Nature and Properties of Soils." McMillan Publication Co. Inc., New York, NY.

Required Inputs

Both yield measurements and soil tests require considerable effort. In the first case, an observation system has to be set up, and local people have to be trained as observers and periodically supervised and aided. Finally, the data have to be collected, recorded, and interpreted. Similarly, soil sampling also takes time. The samples have to be processed, results interpreted, and so on. For either method, one mid-level project staff person will be required for the sampling for at least 4 to 6 months per year, even for a small project. To cover a big project area, as many as 10 field locations and 10 person-months per year may be required. Other investments include approximately $1,500 a year per location for material (basic tools like shovels and scales), shipping costs, and laboratory charges.

Limitation of Yields and Soil Productivity Indicators

One limitation to simple yield comparison is that it does not exclude outside factors such as plant diseases and epidemics that can affect yields. Another point to keep in mind is that crop yields vary from year to year. Even if all else is equal the weather during a growing period (particularly rainfall) greatly influences harvests from one season to the next. Thus data on farm yields can reflect many influences.

Therefore isolating project impacts on soil productivity is not as straightforward as it may seem at first. Long-term observation and data on precipitation, temperature, and other meteorological factors will be necessary to provide an accurate assessment.

Long-Term Value of Yield and Soil Productivity Data

If gathered over several years, specific data on the types of crops grown and their yields, can be extremely valuable for future comparison. Perhaps less important, but nevertheless meaningful, are results of soil analyses over the same time period. The soil analysis can provide insight into the

development of trends, including trends that resulted from project interventions.

3.5 Natural Vegetation Ratio

What and How to Measure

Within a given perimeter (village, valley, watershed, or region), a permanent vegetation ratio can be computed by dividing the total surface area covered by natural vegetation by the total surface of areas covered by farmland or open land (e.g., wastelands, uncovered mine spills, open sediment plains, or sand dunes).

One quick way of determining this ratio is to use existing aerial photographs to estimate the surface areas. Where photographs of vegetation are from different dates, changes in the extent of permanent vegetation cover can be determined without much further data collection. In particular, wide-angle shots showing opposite slopes and landscapes are helpful.

Another method is to run transects along roads and measure the stretches of different land use immediately adjacent to the road. When investigators use this technique in its simplest form, they need only to distinguish between areas covered with at least some natural vegetation and areas without natural vegetation (weeds in farm fields should be excluded). The ratio is then calculated in the same way as already described. The location of the transects must be described or marked clearly so that years later it can be found and the same procedure repeated.

A third method is to choose a particular location along a major road and take photographs of the countryside on both sides of the road and calculate the ratio. If the road has milepost markers for easy identification, so much the better. If the procedure is repeated at regular intervals, the photographs obtained will provide a good record of the changes in the vegetation cover. Many other schemes can be invented along similar lines.

When and How to Measure

The best time to measure vegetation coverage is once a year, just before harvest time, when the difference between naturally covered areas and other types of vegetation coverage is clear. Repeat observations must be carried out at the same time each year. One recording every 5 years is sufficient for long-range

observations. A combination of measurements can also be used, for example, out of 10 different runs,[7] two can be measured every year, but all 10 must be measured every fifth year.

Interpretation

It is generally true that the higher the natural vegetation ratio in a landscape, the better the condition of the natural resources. By comparing coverage ratios of the same location over several years, investigators can identify the evolving trends.

Required Inputs

The inputs needed to apply this indicator are relatively inexpensive. One person can cover much ground in a week, whether it is to compare photographs, run transects, or visit sample plots.

Limitations

Again the basic limitation of comparing the extent of natural vegetation with other surface areas is that the method is simplistic and does not account for some important influences--for example, the condition of the natural vegetation, or the effect of well-tended farmland on the soils versus that of over-used, open areas with uncontrolled grazing. But monitoring changes in the ratio of natural vegetation over time does give a quick indication of land pressures and how they are changing.

The transect method also poses limitations. Frequently, land use immediately adjacent to roads is quite different from land use away from traffic. Consequently, a land survey based on road transects risks being heavily skewed, and thus may lead to false conclusions. Although more time-consuming and laborious, establishing permanent sample strips or plots away from roads eliminates this drawback.

A much more sophisticated and accurate procedure is described in a paper by McCracken (A.I.D. Occasional Paper No. 34, Impact Indicators for Measuring Change in the Natural Resource Base, PN-ABC-903, see section 2.1.6, p.9, on Soil Resource Indicator No. 6, which addresses land use in relation to sustainability and capability of land). However, the procedure

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[7]A path, line, or track along which systematic observations/measurements are made and recorded.

described by McCracken requires that a land capability classification be performed in areas under investigation, a procedure that demands considerably more resources, (in terms of cost, time, and staff expertise) than the quick, project-level data collection activities advocated in this paper.

3.6 Composition and Density of Natural Vegetation

What and How to Measure

Regardless of the vegetation type (e.g., steppe, dense forests, wetlands, or savannah), quick inventories of species composition and density in carefully selected sample areas provide relatively complete information. The main objective is to find out what species are present and how frequently they appear. Standard texts on vegetation analyses provide various methods for measuring natural vegetation. Special procedures have been developed for measuring forests and rangeland in different ecologic conditions (e.g., wet or dry areas, mountainous or flat areas, warm or cold climates).

In the case of a natural forest stand, a list of the dominant and subdominant species with comments about their relative frequency can provide an initial point of reference. In relatively open stands, there are various methods for determining frequency. One of the fastest is a method called "Wandering Quadrants." The investigator selects a direction (bearing) that is retained throughout a "run." He or she then stands in front of the first tree marking the beginning of the run, strikes a 90-degree angle with his or her arms with the angle pointing toward the original direction and walks, counting the paces to the nearest tree within the quadrant defined by the outstretched arms. The investigator measures the distance to the second tree and records its species, size, shape, and any other noteworthy characteristics. The same procedure is repeated, this time starting from the second tree. Once the run is completed, the average distance between the trees is calculated to provide the tree density count; the percentages for species composition are also calculated, and--if more detail is needed--preliminary estimates of volume, biomass, and so on are added using the data derived from the observations.

In denser stands, various standard forestry inventory procedures apply. But in both open and dense stands, the main task is to find out what species are present and how frequently they appear.

When to Measure

In areas where cutting, grazing, fires, and the like are creating intense pressures on natural vegetation, environmental changes can be dramatic. In such areas and in areas in which conservation or revegetation interventions have been successfully implemented, yearly observations in late spring (when flowers are at full bloom) will provide indication of the evolving changes. In other cases, records taken every 2 to 5 years are sufficient.

Interpretation of Data

In interpreting the data, project staff should rely on assistance from the local population, agency technicians and researchers, teachers in local universities, or vocational training centers. Local people have a good feel for which plant species are desirable and which ones are less so. They also know which plant species have recently disappeared. Botanists, foresters, or range ecologists can also evaluate changes in species composition and density and assess present conditions as well as predict future trends. International agencies, such as ILCA, ICRAF, or FAO, may also be able to provide assistance.

Required Inputs

A small team of specialists (e.g., botanists, foresters, range economists) can in one week make an initial observation of the natural vegetation cover in a large area. Of course, a prerequisite is that at least one member of the team be able to identify (or know a source that can identify) the plants in the area. Depending on the terrain, and particularly if aerial photographs are available, an experienced team can cover up to 5,000 hectares a day, at least for an initial assessment.

Limitation of the Indicator

The main problem with this indicator is its statistical relevance, especially when assessing a vegetation type that has not been analyzed before. Without sufficient sampling to bring the reliability of the data inside set limits, there is no way of knowing how meaningful such quick, first assessments are. Moreover, if the measurements are used as baseline data for later comparison to determine changes, sampling errors made at the beginning can lead to dangerously false conclusions. One way to avoid this problem is to establish permanent sampling locations, either in the form of transects or permanent markings on a series of independent sampling points. In this way, the same area and

the same plant communities can be observed over time. However, these measures still do not guarantee that the sample plots or strips are really representative of the rest of the vegetation in the vicinity.

Long-Term Values of the Indicator

If minimum accuracy has been obtained in making the first observations and the procedure has been accurately described for future reference, the data collected can be extremely valuable for additional, more in-depth studies. The above procedure observation can be regarded as forerunners of a more sophisticated survey to establish plant-community inventories. Such surveys repeated over time, give a more precise view of trends in natural vegetation patterns. Early records of this kind will provide an indication of what changes have taken place, which is the ultimate aim of these efforts.

3.7 Tree and Shrub Cover Percentage

What, How and When to Measure

Tree and shrub cover in farmland or in open areas (wasteland, dunes, sediment plains etc.) is measured by calculating the percentage of total area covered by the crowns of trees and shrubs. The resulting data provides a "tree cover percentage" of a landscape. Groundcover (i.e., grasses and the like) is not counted; only trees and woody shrubs.

Careful ground observation using spot-checks and measurements of an adequate number of sample trees and shrubs are necessary to provide fairly accurate data. Investigators measure the area an average tree crown covers. They then count the number of trees in the sample area and multiply this number with the average tree cover value. Finally, they relate the result to the total area included in the analysis to get a first rough estimate of the total tree cover percentage.

Aerial photographs can be of considerable help in this effort, especially if large areas are being assessed. Photographs of the same area taken at different times can be compared. In many cases, the differences are striking and speak for themselves.

Not all tree species provide the same protection against rain, wind, direct sunlight, and so forth. Other factors include groundcover vegetation, organic content of soil, soil erodability

and steepness of slope. Experts have developed formulas to take these factors into account; but as a first general measure, determining simple tree/shrub coverage, as described above, is sufficient for producing a first approximation.

Tree/shrub coverage is measured once a year, when foliage is at its height.

Interpretation of Data

Interpretation of data is straightforward. Although not scientifically supported, the basic idea is that the more trees and shrubs there are in an open landscape, the better is the state of the natural resources. In other words: the higher the tree/shrub cover percentage, the better.

Limitations

The method proposed in this paper only provides a first indication of the relative abundance of trees and shrubs in an open, unprotected landscape. But as mentioned above, there are other influences, such as natural resource management, that also affect vegetation cover in open areas. In addition, no adjustments are included in this rough approach for species diversity.

Long-Term Value of the Tree Cover Percentage Indicator

Comparing tree cover percentages of a given landscape over time provides indirect, but nevertheless valuable, clues to the pressures on natural resources, especially natural vegetation in open, farm-type landscapes. The procedure is useful as a start for tracking changes, provided it is repeated and resulting data compared.

3.8 Wildlife Population

What and How to Measure

There are several ways of estimating wildlife populations. Periodic and systematic animal counts taken at pre-selected observation points or along lines or paths give an idea of the kind and number of animals living in a given area. If these counts are repeated over time, changes in the size of one population can be seen. Another method consists of systematically recording (again, over time) the frequency of tracks or droppings observed.

To establish a baseline, investigators must first prepare a complete list of animals in the area under study, including estimates of the number of species and their frequency given in descriptive terms: for example, species is abundant or sightings have been rare. Traps that will not harm animals (so that animals can be released after they are counted) can also be used to obtain an idea of the type of animals found in an area. The "catch-ratio" (number of animals caught per season divided by number of traps) will give a relative indication of the animals present in an area. Less direct methods involve observing and recording the effect animals have on this environment. Evidence of forage consumed or damage done to vegetation by trampling, bedding-down, scratching or burrowing, all provide leads on the numbers of animals present.[8]

Local people can provide considerable information on the relative frequency and past trends in numbers of animals, including fish, that are, or have been, subject to hunting.[9] Subsequent surveys of areas recently placed under protection (e.g., reforestation and revegetation areas) should be carried out to show changes in the number of endangered species, (i.e., increasing, decreasing or stable).

To estimate the number and frequency of consumable fish species, catches by local people can be checked, weighed, or otherwise quantified.

When to Measure

Surveys should be carried out at least once a year, depending on the importance attached to the species under study. Surveys of upland game and fish should be made at the same time each year because these animals migrate seasonally. Comparison of survey results over a number of years will provide an indication of the evolving trends.

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[8]For more information on animal census, see (1) AAAS, 1983. Resource Inventory and Baseline Study Methods for Developing Countries. Francis Connant et al. (2) Natural Resources Council, 1981. Techniques for the Study of Primate Population Ecology. Committee on Non-Human Primates. National Academy Press, Washington, D.C.

[9]Rapid appraisal methods for interviewing local communities could be used for this purpose. For a discussion of such methods, see Kumar, Krishna. 1987. A.I.D. Program Design and Evaluation Methodology No. 10. Rapid, Low-Cost Data Collection Methods for A.I.D. Washington, D.C.

Interpretations of Survey Results

A list of existing species offers valuable information about the state of wildlife in a particular area. It also provides specialists with further insights into changes occurring, not only with regard to wildlife, but also with regard to the ecology of an area in general. In many ways, wildlife reflects an area's ecological balance. Changes in the ecological balance immediately, often drastically, affect the local wildlife population. If the wildlife population changes, chances are good that either water, soils, or vegetation resources have undergone recent changes as well.

Required Inputs

Surveys should be carried out by people who know the area under study and its wildlife and habitats. The effort involved depends on the size of the area and how much wildlife exists. In some instances, a full crew may be busy for several months out of the year; in other cases, the rounds are made fairly quickly by one or two people. In all cases some systematic efforts are needed, depending on the approach selected, to establish counts.

Limitation of Wildlife Surveys

Because of the importance of wildlife to the ecological balance of natural resources, this component deserves much more attention than it has had in the past. Developing country governments and donor agencies are just beginning to understand the importance of wildlife, not only as game or tourist attractions, but also as an important indicator of the state of the natural ecosystems in an area.

Although animal conservation problems seem overwhelming at times and trend reports are generally discouraging, project personnel should still make a serious effort to find out more about what animals exist in project areas and what can be done to manage game and fish resources more effectively. In many cases, such efforts necessitate a more thorough analysis of the state of wildlife than the one proposed above. Nevertheless, a first review of the situation is useful in determining whether a more complete inventory is necessary. Even without a follow-up study, this will yield valuable insights into what changes or trends are occurring that otherwise would take much longer and more money to identify.

Long-Term Value of Wildlife Surveys

Even an initial cursory set of observations on the state of wildlife is better than having no information at all. Depending on the accuracy and the completeness of the data collected, these observations can be of considerable use to future analysts and resource managers.

3.9 Wildlife Habitat

What to Measure and How To Interpret the Data

The measure of the quality or adequacy of wildlife habitat depends on the needs of individual species. Generally, an adequate wildlife habitat consists of such elements as available feed, water, physical protection against enemies, special places for offspring to develop, space for animals to roam (or migrate to and from), and so on. Some of the characteristics of wildlife habitat are described under other items already mentioned: for example, vegetation composition and density or water quality and quantity.

It is highly recommended that, where possible, in-country wildlife specialists be consulted, for example in defining specific indicators for rapid appraisals of existing or potential habitats in or nearby project sites. Assistance from specialists is also required for an accurate interpretation of data.

When to Measure

The best time for carrying out surveys of animal habitats depends on the species involved. Many animals migrate at different times of the year to different locations. In addition, resources like water and vegetation vary with the seasons. Therefore, on this subject as well, project staff should seek the advice of in-country specialists.

Required Inputs

The required inputs for assessing wildlife habitats vary according to the scale of the total natural resource assessment. It is important to keep in mind that the scale of inputs for applying this indicator must be in line with those expended on the other indicators. Most often, only the most essential information can be gathered with the limited means available.

Frequently, the best initial assessment can be obtained by directly contacting someone who already knows wildlife habitats in the area. In some cases, a preliminary look at fish (or other aquatic life) habitat may also be warranted. This too should be undertaken by someone who already knows the situation.

Limitation of Wildlife Habitat Indicator

The main problem with this procedure is that, to produce meaningful data, it will require a long-term effort and the input of specialists at various stages. It may be difficult, if not impossible to meet this requirement, given the short duration and limited funding for monitoring and evaluation activities of most A.I.D. agricultural projects. However, the problem is not impossible to resolve. On the contrary, with some forethought and planning, and little extra cost, project designers can include a provision for the data collection activities to be continued by a local institution (e.g., university or government agency) after project completion.

Long-Term Value of Wildlife Habitat Indicator

Often, trends in wildlife habitats become apparent in the long-term; some of the project-induced changes in habitat may not occur for some time. Habitat tracking, therefore, should be carried out over the long term. Therefore, clear, accurate records are necessary to enable others, over time, to compare the data. The data may also be of use to those who have entirely short-term objectives.

3.10 Unique Areas

What and When To Measure

"Unique areas" refers to areas of special, scientific cultural, historical, religious, recreational or scenic significance. The nature of these areas may vary greatly from one project to the next. For example, sacred forests, historic sites, unique flora or fauna, archaeologic or geologic sites, rock paintings, hot springs, old cemeteries or special grave sites, ritual areas (sometimes off limits to all but the initiated) and traditional or modern monuments, either man-made or natural, are all included under this category. Because of the variety of areas, only the most general guidelines can be provided here.

Project staff should survey the area and ask local people about areas of special interest. Local and international specialists in history or natural history may be able to provide additional information. The essential task is to inventory all sites and to provide as complete a description as possible of their current state and the hazards they are exposed to.

Surveys of special areas should be made as early as possible in the project cycle, ideally during the project design stages.

Interpretation, Required Inputs, Limitations of Data, and Long-Term Values

It is recommended that overall efforts under this indicator be consistent with other monitoring activities. Of primary importance is information leading to a description of changes taking place as a result of project interventions. However, because the required data varies so much from site to site, it is almost impossible to provide specific recommendations in the general context of this paper.

4. CONCLUSION: SUGGESTED USE OF INDICATORS

4.1 Project-Level Use

The data gathered by analyzing each indicator now needs to be placed in perspective in order to get an overview of how, if any, changes have occurred to the natural resources of an area. This can be done by tabulating the results of the analysis in the way described in the following sub-sections.

Step 1: For each of the 10 preliminary indicators described (summarized in Table 2), the following basic question needs to be answered: "What effect did the project have on the different indicators such as water quantity, water quality, soil erosion, soil productivity and so on?"

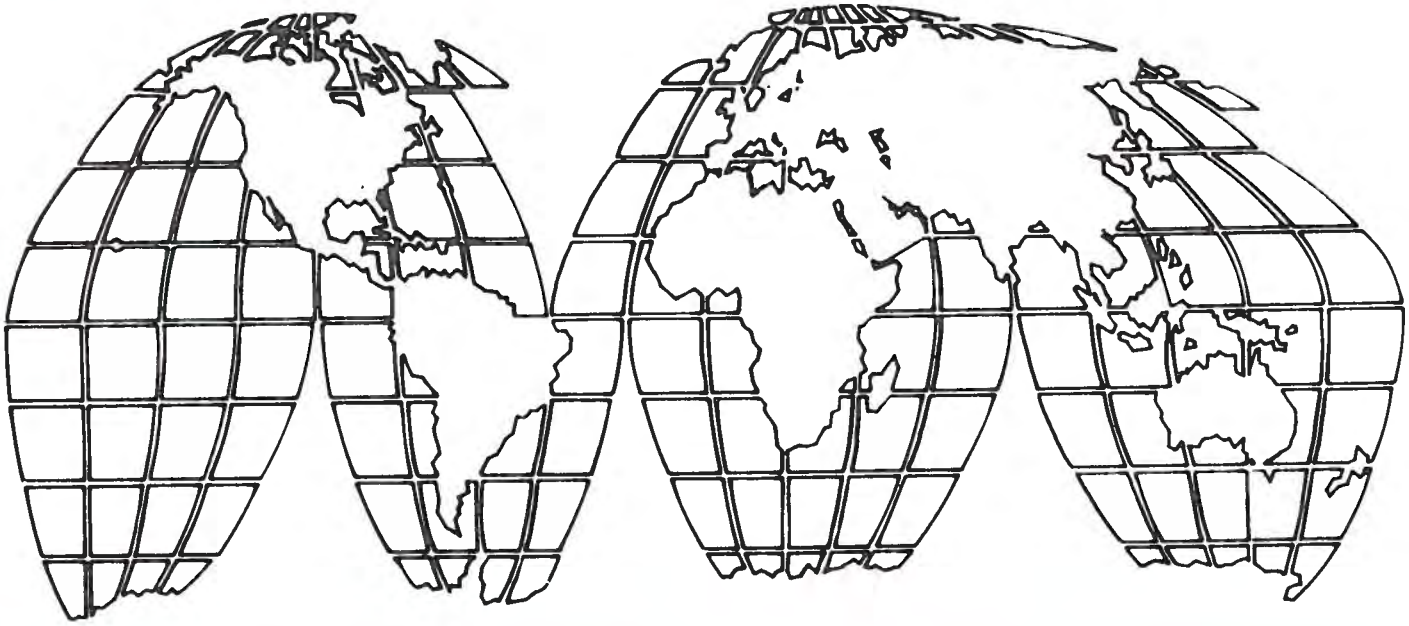
Note that (1) not every activity will have an effect on all resources covered by the 10 indicators, and (2) effects can be either positive or negative, and they can vary in extent (high, medium, or low). Much depends on the size of area affected and the number of people involved.

Step 2: Table 2 must be completed by putting an "X" in the appropriate box. Note that high, medium, and low are relative terms; generally, high indicates significant obvious impact felt

by many people and/or affecting large areas (the entire project site, for example); medium indicates some impact, somewhere between high and low, and low indicates no significant impact or noteworthy problems. Because these terms are relative, judgment is required when using them.

Table 2. Summary of Project Resource Impacts

	Positive Effects			Negative Effects		
Indicator	High	Med	Low	High	Med	Low
Water						
Quantity						
Quality						
Soil						
Erosion						
Productivity						
Vegetation						
Permanent Vegetation Ratio						
Natural Vegetation						
Vegetation in Open Areas						
Wildlife						
Wildlife Population						
Wildlife Habitat						
Unique Areas						

Where it is estimated that there are no effects or that impacts are insignificant, mark "0"; where impacts are uncertain, unknown, or not yet evident, mark "?."

Step 3: Based on the completed table, a series of decisions can be made: