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Problems and Objectives in Remote Sensing Field Work

PROBLEMS ENCOUNTERED IN FIELD WORK

Many published remote sensing project reports have a strong emphasis on image processing techniques with very little detail regarding the methods used for collecting data and information in the field. One may read some reports and wonder whether the researchers even found it necessary to do field work or to use maps, aerial photographs, or other reference materials. As a result, new researchers looking for information on remote sensing field methods often must start from scratch by scouring the literature of related disciplines for guidance. Frequently the result is that the field methods for a remote sensing project are poorly planned and the final product has hidden weaknesses that could have been avoided by careful advance planning.

Since most remote sensing projects require some amount of field work, there should be significant benefits to a systematic approach to planning the field portion of the project. Certainly, the final product will be more reliable and defensible if the field work and the use of reference materials are planned and executed properly. Even weaknesses in the final results can be stated openly if the unavoidable deficiencies in field work and reference materials are known and explained. There is a tendency among researchers to avoid mentioning weaknesses in their methods, even when those shortcomings are beyond their control. Eventually someone, perhaps in a thesis defense, will ask about field methods or ancillary materials used, and any shortcomings will come to light. It is best to avoid this embarrassment by recognizing and dealing with these details in advance!

The following is a summary of components that should be considered in planning the field portion of a remote sensing project. The approach to planning field work in remote sensing consists in identifying pitfalls and problems and selecting appropriate solutions in advance (Joyce, 1978). Also, this guide provides some procedures for avoiding problems in the field and for making appropriate measurements and observations. An extensive bibliography on field methods is found in Appendix 1.

Problem 1: Lack of Clear Objectives for the Project

It seems self-evident that one must have objectives before beginning a project. However, often the objectives are not thought out in sufficient detail. A thorough written statement of objectives will set the agenda for the entire project and will determine which methods should be used at every stage of work. The planning of objectives will depend in large measure on the expected result, or the nature of the final product. Whether the result is a map or a research report describing a biophysical model, preliminary planning is essential. The examples given in this section assume that a map is the final product.

Initial planning provides the foundation for all subsequent steps in the project. A comprehensive statement of objectives should include the following items: (1) location and size of area; (2) scale of final maps, if maps are the final product; (3) proposed accuracy of the final result; (4) purpose and end users of the final product (i.e., who will use the final maps or models, and how will they be used); (5) anticipated legend of the final map (initially this is a rational legend, based on what one hopes to show on the map, but subsequent reality may result in a modified classification based on what is feasible); (6) types of image data, photos, and other reference materials to be used; and (7) field methods to be employed.

Each of these components of objectives statements helps determine the methods selected for field work, including sampling procedures, locational techniques, and details of methods for making observations in the field.

Problem 2: Lack of a Valid Sampling Plan

Much of the planning for a field project must consider the difficulty of assuring the representativeness of field samples. Map accuracy depends greatly on the degree to which sampled data truly represent the land surface. This involves acquiring a sufficient number of samples in each category to be mapped and assuring that the aggregate of samples represents all the variation within each category. Failure to achieve this is one of the most frequent but preventable errors made in field work in remote sensing, and usually can be attributed to collecting too few samples.

Some methods of data classification used in remote sensing assume that data points have a random distribution over the study area. Often this assumption is ignored during collection of samples in the field, and the resulting map accuracy is compromised. If field data cannot be collected in a way that satisfies statistical assumptions of the classification program, then a less restrictive program should be used. The accuracy of the final map might be just as good with an alternative data classification program, but analysts should reveal that a program of less statistical rigor was used. Data analysts should understand how to choose a classification program and how to demonstrate that their data are suitable for that program.

Problem 3: Difficulty in Dealing with Scale Differences

This problem is one that initially overwhelms an inexperienced field person. The high resolution of the human eye at a distance of only a few feet presents such an abundance of ground information that one hardly knows how to relate it to the level of generalization on images and air photos. Field work consists largely in collecting information that can be scaled up by aggregation to correspond to information on images. To do this one must visualize the extent of a "ground pixel," which is the area of ground coverage represented by an image pixel. Then it is necessary to collect and aggregate ground data to best represent one or several image pixels.

Problem 4: Errors in Location

With a georeferenced image and a global positioning system (GPS) receiver, locational problems are greatly reduced, especially since the U.S. government's removal of selective availability, which occurred in May 2000. However, it is still difficult to be certain that a field location is accurately tied to a single specific image pixel coordinate. For this reason, it is necessary to estimate a potential locational error in pixel units and adjust the ground sample unit size accordingly. The potential for having a damaging locational error is highest on surfaces that have a high frequency of variation in cover type (e.g., urban areas). Large homogeneous areas allow some locational error without damaging effects as long as the location is not near a category boundary. Field of view (FOV) of the sensor also influences the precision with which location needs to be determined. Sensors with greater FOV allow more latitude for location errors than sensors having smaller viewing areas do.

Problem 5: Inappropriate Observations and Measurements

The question of what to measure, how to measure it, and to what level of detail it should be measured is still one of the greatest questions to field personnel. This issue is also given the least attention in many published articles. When searching theses and dissertations, one sees considerable attention given to measurement details, but when the work appears in a publication, measurement details are greatly abbreviated or missing altogether. The level of detail collected may be insufficient to meet the overall objectives in terms of the number of categories to be mapped or the level of accuracy targeted for each category. The opposite may sometimes occur when more data are collected than are needed to meet the objectives of the project. This mistake results from insufficient thought given to project objectives and can waste days of valuable field time. Some researchers prefer to err on the side of overcollection of data. They collect everything possible because of uncertainty about which biophysical variables are most significant in the reflectance of a surface material. A similar deficiency in data collection may result from measurement of features that have little or no influence on spectral response in the wavelengths sensed in making the image. For example, measuring water temperature when using visible and near infrared images would result in data that may have no relationship to the image. Any field project should begin with a brainstorming session to identify all biophysical variables that may affect spectral response in the wavelengths under consideration. The biophysical variables actually selected for measurement will be determined by reference to project objectives.

Some of the difficulty is a poor understanding of the relationship between biophysical variables and spectral responses of surface materials. The more a field person knows about the reflectance–absorption–transmission relationships of surface materials, the easier it is to select which biophysical variables to observe in the field. At the very least there should be an awareness of the basic responses of water, soil, vegetation, concrete, and asphalt to solar radiation in the reflective wavelengths. Further knowledge on the variations of these basic responses is valuable. For example, one should know the effect of turbidity on the response of water, the effect of moisture and texture on soil reflectance, and the effects of moisture, cover density, or biomass on vegetation reflectance.

Problem 6: Inadequate Reference Materials

Reference materials, other than field data, include all archival data such as air photos, maps, and any other compiled data that are referenced to map locations, for example, census data. The problem of inadequate reference materials may create more frustration and dilemmas than all other problems combined.

Reference data are considered inadequate when (1) scale and level of generalization of various maps and aerial photographs vary greatly and (2) dates of air photos, imagery, maps, and field work differ by time of year or by more than a few years. Project planners can overcome this difficulty by planning field work to coincide with overflights of satellites and aircraft, provided funds are available. Other projects must make do with poor synchronicity of reference materials by trying to minimize differences between dates or seasonality between reference materials and imagery. Acquisition of reference materials as well as a thorough search of the literature may actually reduce the amount of field work needed.

DEFINING OBJECTIVES

The importance of clearly defined and well-thought-out objectives cannot be overemphasized. A thorough definition of objectives requires considerable thought about each detail of a project and determines field procedures, level of generalization, sampling approach, data processing technique, and final product. In short, everything about the project should hang on the definition of objectives. Furthermore, the process is greatly helped by writing out the objectives. Plan on writing a detailed project objective statement as a necessary first step of project planning. The following components of such a statement should each be considered, although the sequence is not critical. An example follows the list of components, and although the example is a mapping project, the same elements would be considered in planning projects that generated something other than maps, such as a biophysical model or a validation of results of a previous project. The objective statements must always be thought out thoroughly.

Components of a Statement of Objectives

Tentative Title and Application of the Final Map

This may be the easiest and most obvious step in the preparation of a statement of objectives. The result here should be a name that is as specific as possible. For example, an agricultural survey might be called "Agricultural Land Use" rather than just "Land Use." If the survey was intended for irrigated crops only, then the title might be modified to "Irrigated Agriculture." Thinking about a specific title shapes, at a very early stage, the type of field work to be done. It helps one put an early focus on the features that need to be observed and which kinds of data will be gathered. How the user will apply the map may also be a part of the map title, for example, "Irrigated Agriculture for Estimating Water Consumption." This helps clarify a rationale for doing the work in the first place, as water managers would have an interest in applying water consumption of particular crops to a map of crop acreage.

Location and Size of the Study Area

An important determinant of location of a study site is often the availability of reference materials and image data. It is frustrating to select a study site and then find there are no data or adequate maps to use for reference. This problem may be unavoidable when project areas are selected by a client or other outside party.

An important factor in determining the appropriate size of a study area is the areal extent and uniformity of categories to be mapped. If a grassland or forest is being mapped, the typical low frequency variation may require a larger area in order to incorporate the necessary categories. On the other hand, an urban area presents a challenge at the opposite extreme in which even the smallest area contains a high frequency of variation both within and between classes.

There is a tendency among researchers to take on too much work for the available time and resources. Defining too large a study site is a common error. The optimal size of a study area is determined by the amount of time and money available, the number of people available to work in the field, the time required to collect data in the field, and the mode of travel possible in the field; for example, agricultural areas usually have many roads, but wilderness areas will require some travel by foot. Each of these variables should be thought out in detail and may have to be modified as the exact procedures for observations and data collection become more clear. Bigger study areas do not necessarily make a better project. The quality of project results may be improved by choosing a smaller area and working more intensively, rather than spreading effort over a large area with fewer data points. As with many issues in project planning, there is no single correct solution, only factors to be weighed.

One ever-present factor that must be considered is permission for access to a field site. If the proposed field site includes privately owned land, always ask the landowners or tenants for permission to enter. Be ready to explain in straightforward terms what the project is about and what a field crew will be doing on their land. Ask them which roads field personnel may use, and find out where to expect livestock. Assure them that all gates will be left as found, either closed or open. In some places strangers are not trusted, especially if they appear to be connected to government agencies. Advance contacts with local residents will ease their suspicions when they see strangers in unfamiliar vehicles in the area. If permission for access to crucial locations cannot be obtained, other study areas might need to be considered.

Probable Legend of the Final Map

As a practical matter, some project operators derive the map legend as a result of what is spectrally possible to map. Ultimately, reality overcomes idealism in the final stages of a project, and one must map what can be mapped. However, if the project begins with this approach, there is little to guide decisions on field procedures. Without a preconceived notion of a map legend, one runs the risk of measuring either too much or too little during time in the field. Remember that field time may be the most expensive element of the entire project, so use it wisely.

The map legend need not have the same level of detail in every category. For example, in a project mapping irrigated agricultural land use, dry land agriculture and settlements may each be a class without subclasses, while the irrigated land might have a category for each crop type, with subcategories indicating crop vigor and cover density. Identifying these differences in the map legend plays a useful role in planning what needs to be done in the field.

Obviously, some time needs to be spent in the dry farm area looking at the variation that must merge into a single class, but few measurements will be needed. In the irrigated areas one may need to observe crop type for each field, the stage of growth ranging from bare ground to ready for harvest, and the health of the crop. In addition, measurements may be needed to determine crop height and cover density. In this way the map legend becomes tied to field procedures. If one finds that certain intended classes are so similar spectrally that they cannot be mapped by the available remote sensing method, then class merging will be necessary and the legend will be altered. This decision may be made at a very early stage when first viewing the result of a cluster map of the image data for the study area.

Map Scale and Level of Map Accuracy

It may sound too presumptuous to attempt to set a target for map accuracy before the project even begins. However, this issue is not a matter of wishful thinking and ambitious goals for a perfectly accurate final map. Rather, it is a matter of thinking about the relationships among map scale, level of generalization, and accuracy. As a general rule of thumb, as map scale becomes smaller (larger areas), mapping units (cells) and categories are aggregated, causing map generalization and accuracy to increase. Keep in mind that one 20-meter (m) pixel of Thematic Mapper (TM) data will appear as a spot 0.83 millimeters (mm) wide on a 1:24,000 scale map. Imagine the headaches of field work if one attempted to produce a final map with this level of detail. The resulting map accuracy would likely be very low, assuming it is possible to find pixel-sized locations in the field precisely enough to match with image pixels to assess accuracy.

As mentioned above, the number of map categories and the homogeneity of cover within categories also affect map accuracy. Unfortunately, there is no good rule of thumb for predicting final map accuracy, but there are some elements to consider. If there are six or fewer map categories in the legend, and each is somewhat homogeneous, overall map accuracy of 90% or better is a reasonable expectation with comparably high accuracy in each category. As the number of map categories and cover variability increase, map accuracy, overall and by category, will decrease. In a complex surface with many map categories and a map scale of 1:24,000 or larger, plan for an overall map accuracy of 65–70%. The final result may be better. As we will see later, the number of field samples needed for classification depends on the expected level of accuracy.

Types of Image and Reference Data to Be Used

Ideally the selection of image data is based on the objectives described up to this point. The appropriate wavelength bands, and the resolution (spatial, radiometric, spectral, or temporal) for detecting and mapping the phenomena in question determine the image data selection. Seasonality also often influences the choice of image data.

The selection of a study area is often influenced by the availability of reference materials, including air photos, existing topographic maps, cover type maps, soils maps, census data, and maps. Acquire everything.

Preprocessing and Classification Approach

This guidebook is not intended to discuss classification techniques, but since the issue should be mentioned in a statement of objectives, a few comments are in order. First, know the statistical structure of the image data, and select classification algorithms whose assumptions are not seriously violated by the data. Keep in mind that the maximum likelihood classification method, though quite rigorous, assumes a normal distribution of data. If necessary, consider data transformations as part of the preprocessing to make the data better match the assumptions of the classification algorithm. Second, consider a layered classification approach, beginning with cluster analysis followed by a supervised algorithm. These issues are thoroughly discussed in Jensen (1996). Many remote sensing personnel use the classifier that gives the best result regardless of the data structure. If the results are optimal, perhaps the statisticians' advice can be ignored with a clear conscience.

A Statement of Objectives

The following example states the objectives of a study of irrigated agriculture land use, as mentioned above. This statement is for use in project planning. An actual project proposal would, of course, elaborate extensively on methods and other details.

Example

In order to learn more about the consumption of water for irrigation, it is important for water managers to have reliable information on the types of crops and their acreage (shows application). The objective of the project is to map the crop type, stage of growth, cover density, and acreage of irrigated agriculture in White County within the limits of the South Fork 1:24,000 U.S. Geological Survey (USGS) topographic map (shows location, map coverage, and scale). The final map will display categories including sugar beets; corn, new growth; corn, mature; alfalfa, recent cutting; alfalfa, mature; bare ground; pasture; dry farmland; settlement (shows legend). Based on a minimum unit area of 10 acres at a scale of 1:24,000, and a random sample of measurements taken within each field, the final map will strive for an 85% overall accuracy and 80% or better accuracy for each category. Each 10-acre unit will show the dominant cover type for that location (shows expected accuracy and cell size). Accuracy analysis will be done by field work and air photo analysis to produce an accuracy matrix. The primary data will be Landsat TM selected to cover the area in late August before harvest near the end of the water consumption season. Reference data will consist of field updated air photos of a date as close as possible to the TM data. Other reference data will consist of crop data from the White County agricultural agent, topographic maps, soil maps, and water allocations for each parcel of land (shows image type, date, and reference sources). Data processing will consist initially of atmospheric corrections in each band of the TM data set. Classification of TM data will begin with cluster analysis, followed by comparison with reference data for class merging. Final classification will be done by a minimum distance to means algorithm (preprocessing and classification approach).

PLANNING FIELD WORK BASED ON OBJECTIVES STATEMENT

Assume that it is now spring or early summer and time to select TM overflight dates for late August or September prior to harvest time. Field work can be divided into tasks to be accomplished before the TM overflight, during or near the time of TM overflight, and possibly work to be done after the TM overflight.

Field Work before Overflight

Before going to the field, remote sensing personnel should investigate the availability of aerial photographs and satellite imagery, and place orders as needed. TM data may be ordered from Earth Observation Satellite Company (EOSAT) at 4300 Forbes Blvd., Lanham, MD 20706; 800-344-9933. Also practicing field measurement methods with instruments is important. This preliminary work trains field personnel in the methods and use of instruments, and determines whether all equipment is operating properly. Contingency plans should be made to cover unexpected events, such as bad weather or equipment failure.

Considerable effort may be required to update air photos. If the project has resources sufficient to pay for air photos taken concurrent with a TM overflight, then an air photo update is not necessary. If the air photos are from some previous year, then this task requires going to the field after crops have begun to grow in order to identify the changes in fields that have occurred from the time of the photo overflight. For example, some fields that are bare or fallow in the air photo may have a crop in the current year.

Field Work during or Near the Time of Overflight

Identify crops and make appropriate physical measurements for each category of irrigated crop at randomly identified measurement sites. Identify land cover in dry farm areas at sample sites for each crop type. Identify settlements and other built developments.

Field Work Done after Overflight

In this example, all measurements must be made near overflight time because it is scheduled just before harvest. After harvest any field work that involves measurements will be of little use. Details of permanent developments or settlements may be observed or measured anytime before or after an overflight.

This example demonstrates the use of preparing a complete statement of objectives as an aid in planning field work. The rest of this guidebook is designed to help in the execution of the field work and will provide details for some of the points covered in the statement of objectives.

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