Quantifying Agricultural Indicators of Desert Encroachment

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SUMMARY
Point and cell measurements are being added to an area sampling frame in Morocco to provide for quantifying certain agricultural parameters that relate to desertification. The technique is modeled after the primary sample unit and point measurements used by the Soil Conservation Service, United States Department of Agriculture, in its National Resources Inventory.

INTRODUCTION

The Remote Sensing Branch of the United States Department of Agriculture's (USDA) Statistical Reporting Service (SRS) has been assisting Morocco and several other countries in developing area sampling frames to measure agricultural production. In Morocco, supplemental sampling is being added to the area sampling frame in an effort to determine whether desertification is occurring. The supplemental sampling is modeled after the sampling techniques used for the National Resources Inventory (NRI) of the USDA Soil Conservation Service. (Goebel and Schmude 1980). For this inventory certain data are collected for sample areas and more detailed data are collected at random points within the primary sample unit areas.

Various techniques of remote sensing are used in the development of the SRS area sampling frames. LANDSAT and aerial photography, along with the best available maps, help statisticians stratify the area to be measured. The area is divided into strata of similar types and intensity of agriculture. Each stratum is subdivided into count units and segments, which are then statistically sampled for data expansion to yield estimates (Cable 1981).

Background to the Morocco Studies

Three other kinds of sampling frames had been used in Morocco, but none could provide the kinds of data needed to measure agricultural production and changes in the resource base.

The population frame is a census conducted by qualified personnel in the field. This census is exhaustive and representative of all households, but it produces few meaningful agricultural statistics. Morocco's rural population is not all rural, the census included no stratification by farm size, and the last census was in 1971.

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Another sampling frame, the rural tax frame, was the basis for a 1962 census designed to list every element falling under the land tax, including land, tree, and livestock ownership. The tax frame contains significant underestimations of area despite efforts to verify accuracy of landowner statements. Furthermore, it was based on ownership rather than farming activities.

To overcome some of the inadequacies of the census and tax frames, the operator list frame was developed. In 1976 the Ministry of Agriculture and Agrarian Reform conducted an exhaustive census of all Moroccan farmers. Farmers were grouped by villages and, as a whole, make up the sampling frame, which is used to obtain a representative sample of farms. This frame, however, has three disadvantages:

1. The Moroccan village is complex--a combination of family, household, and territorial relationships;
2. Verification of statements is difficult; and
3. Rangeland is difficult to evaluate because it is not controlled by individual farmers.

In October 1979 these difficulties led the government of Morocco to use the area sampling frame in a pilot study of Kenitra, an important agricultural province. Most of Morocco's major crops are grown here, and the province also has large areas of irrigated land. Data collection was completed in early 1980, and data were summarized with hand calculators.

The pilot study was a success; sampling errors were at acceptable levels and other errors were largely due to start-up problems. In September 1980 the pilot study area was expanded. Data were collected during spring 1981 and summarized manually for the four major cereal crops. A yield survey was completed in June 1981, and plans are underway to complete the stratification of all the northern provinces in 1982.

Environmental Changes caused by Agriculture

The area sampling frame has proved an effective tool for estimating crop area in Morocco. But what about accurate measurements to determine whether desertification is taking place and, if so, at what rates?

In Morocco, as in many other arid and semiarid regions, agricultural pressure sometimes exceeds the capability of the land and climate to sustain productivity and the resource base. Extensive dryland farming is practiced in areas in Morocco with annual rainfall averaging less than 250 mm. Water, sometimes of marginal quality, is used for irrigation where available. Farming practices have reshaped the landscape in mountains and narrow valleys as well as on the plains. Contour furrows and long, narrow depressions are constructed to trap water for tree and shrub plantings. Terraces and benches built both by hand and by machine allow for maximum use of the limited precipitation.

Accelerated erosion is a major problem caused by inadequate plant cover. In 1981 large areas in Morocco were planted to cereals but there was not enough rainfall to produce a crop. Then, late-season intense rainstorms caused high rates of erosion in some areas where the earlier shortage had prevented growth of an adequate plant cover. Erosion is also accelerated by overgrazing, which occurs almost anywhere shepherds can graze their flocks of cattle, sheep, goats, or camels. Other causes of accelerated erosion include reduced productivity due to insufficient or low-quality irrigation water and the removal of woody species for lumber or fuel or to open up an area for cultivation.

Another problem is blowing sand. Active sand dunes--often more than 15 m high--threaten roads, canals, fields, and villages. Some villages have been completely covered by dunes.

Most other arid countries face similar problems. As we recognize these and other changes occurring in the environment, we begin to question their extent and implications. Are the changes part of a long-term pattern of rapidly fluctuating conditions, or do they signal a potential for irreversible decline? How can we measure agricultural pressures in relation to erosion and changes in the condition of the environment?

Measuring Indicators of Desertification

In recent meetings in the United States, a plan was developed to study various characteristics of arid lands so that changes in the desert environment could be monitored. Another paper presented at this symposium discusses that study, which was carried out in New Mexico. (Risley and Musick 1982).

Many desert conditions fluctuate widely and rapidly with the presence or absence of desert rains. These changes usually do not reflect any lasting change in the desert environment, but slower and almost unmeasureable changes do occur that signal a long-term trend upward or downward. If this trend is toward deterioration, it may be called desertification (Reining 1978). How well can the area sampling frame measure these subtle but crucial changes?

The area sampling frame provides a means of efficiently estimating agricultural quantities and, with successive surveys, quantitative gross changes. Many of the characteristics related to desertification must be measured precisely, however, to allow for identifying small amounts of some kinds of change. For example, in the desert fringe area a segment in the open grazing (pasture and range) area may be as large as 10 km^2. The segment may include several land uses, some eroding areas, and a wide variety of pasture conditions. Numbers of livestock, area and production of crops, and economic and social factors can be quantified by the area frame. But to quantify soil type, slope, and natural vegetation with the area sampling frame, each would have to be measured for the entire segment.

These parameters can be described in general terms for a large area, but general terms are too broad to permit precise measurement of change. "Hot and dry", for example, may be a good description of the desert fringe--but it also describes the middle of the Sahara!

Reining's handbook lists many kinds of indicators--physical, biological, agricultural, and social--and points out that measuring the factors related to desertification requires--

1. repetitive measurement,
2. direct measurement of indicators instead of inferences from other evidence,
3. precise geographic reference to measurements, and
4. careful analysis of data to determine whether changes are temporary fluctuations or indications of lasting change.

In a sampled field it is easy to record the crop grown as well as other types of data such as the yield or whether the field is irrigated or dryland. Data collection is more complex, however, when the parameters to be measured relate to the natural environment rather than man's activities. Soil and slope usually do not follow man's field boundaries.

"Scattered grasses and shrubs" may be accurate but lacks precision as a measurement of arid land vegetation. If a given field was in scattered grasses and shrubs several years ago and is in corn now, we know that change has occurred. But if a field is still in scattered grasses and shrubs we need a more precise identification of the plants and a measurement of vegetation yield to determine whether change has occurred. "Five percent ground cover of woody shrubs with small tufts of closely grazed annual and perennial grasses and forbs" is more precise but is still only partially quantified. As quantification becomes more precise, the area it represents is smaller.

In Morocco, it was decided to use the supplemental sampling modeled after the NRI techniques to address the requirements for repetitive measurement, precise geographic location, and accurate quantification in the desert area. In their paper presented at La Paz in 1980, Goebel and Schmude said:

> "When studying natural resources there are various sampling unit types to consider, e.g. areas, linear transects, points, and volumes; the optimal choice depends upon the characteristic under consideration. The NRI scheme employs both area and point sampling as a compromise between optimality and practicality. Most land use categories are estimated using the point data since these acreages can then be cross-classified by the many resource characteristics being studied, e.g., soil classification, wetland status, erosion estimates, etc. This cross-classification ability can be virtually lost if other methods are used."

In both the NRI and the point measurements being added to the Morocco sampling frame, measurements recorded for the point represent the conditions of the community in which the point is located. If the point falls in a community where small shrubs are several meters apart, the percentage of crown canopy cover can be measured whether the point falls directly on a shrub or between shrubs. The point method also allows us to identify soil characteristics--slope length and steepness--and kinds and amounts of vegetation without delineating the area of each parameter.

In Morocco, to provide the required precision of measurement for these parameters, each segment selected in the range stratum of the area sampling frame will be divided into cells of 4 or 5 hectares. These cells will be randomly sampled and additional data will be collected on the cells or subsegments. In addition, two or three points will be randomly selected in each subsegment. These points will be located by drawing two random numbers to represent the coordinates for each point: starting in the southwest corner of the subsegment, one number provides the distance north and the second the distance east.

By using smaller cells and points it is hoped that desert parameters will be measured more accurately. This will allow more effective and precise monitoring to detect environmental changes when successive surveys are carried out in an area in the future.

CONCLUSION

The area sampling frame is an effective tool for measuring agricultural production. With modification, it can also be used to measure agricultural parameters that relate to desertification. In Morocco, land use will be recorded at the sampling unit. Land use and cover will be recorded for selected cells within the sampling unit. Detailed data on soils and vegetation will be collected at selected points within the cell. When combined with ancillary data, these data will provide a baseline for future monitoring of change in the arid and semi-arid environment.

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