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The Role of Scale in Community Resource Management Programs

by

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INTRODUCTION

Community resource management programs operate on the premise that resources are managed best when the people affected by decisions participate in the design and implementation of these decisions. Finding common ground between government managers and village users of public-domain resources, however, is often difficult. Governments seek to improve the welfare of the district or nation, while villagers seek to survive as a community. Planners need data that have been aggregated by administrative areas (counties, provinces, planning regions), whereas villagers are concerned with the performance of households and the use of individual pieces of land. To be sensitive to the various spatial perspectives from which nations and villages view their resource management problems, planners need to operate on different spatial (and sometimes temporal) scales and to exchange information among these levels.

Ciramaeuwah Girang typifies a village participating in the social forestry program sponsored by the Indonesian State Forest Corporation (Perhutani). A majority of farmers in Ciramaeuwah Girang are landless or possess extremely small landholdings. These farmers rely on state owned forest land to make up shortfalls in agricultural production. The social forestry program trained the local forest guard in community organization techniques. This forest guard has worked with the local farmers to design management plans which define the authority, responsibility, and accountability of the forest users and forest management agency. Management plans have been implemented for three sites and farmer groups have taken responsibility for managing these lands.

While Ciramaeuwah Girang is a successful project, from the national perspective many questions exist as to the usefulness of this approach. How 0generalizable are the results from this village to other villages in West Java or the rest of the country? Once the forest department has learned the lessons of this village, do all future endeavors have to be equally labor intensive? What lessons learned from other parts of the country can be applied in this village? These questions arise out of the fact that planners and villagers view their environment from different spatial scales.

Many community resource management programs focus on individual farms or households. Researchers and planners collect data on who owns what resources, how these resources are managed, and the costs and benefits of managing these resources. But household-scale data are not sufficient in-and-of themselves. The most obvious limitation of a household study is that the scale itself is not big enough for regional and smaller-scale undertakings. Broad-based resource management programs require something more than just an aggregation of individual site results; sites must be placed within a regional environment, economic policy, and program planning context.

Regional scale data are useful for working with larger-than-farm units of landscape analysis and design. Planners can conduct full-scale landscape planning exercises such as developing overall plans for managing a watershed including detailed designs for rehabilitating the lands between farms. Alternatively, planners can examine attributes of land-use systems in different landscape zones and can determine whether opportunities exist for complementary production, for example hillside farmers selling firewood to fuel-scarce commercial farmers in valley bottoms (Raintree 1987). But just as household-scale data could not be used to reach conclusions about a region, regional-scale data are not useful for making generalizations about a state or group of states. Questions concerning units larger or smaller than the region require different scales of analysis.

Interest in scale-related problems, of course, is not limited to community resource management programs. Several recent examples demonstrate this point. In an article on the role of geography in the international agricultural research centers, Bebbington and Carney (1990) argue that relationships between different spatial scales (e.g., what is the effect of growing improved breeds of rice at the field, farm, community, region and nation level) are underdeveloped in the work of these centers. Carter (1987), working at the International Center for

Tropical Agriculture (CIAT) in Columbia, demonstrated the use of a multiple-scale approach to understanding the distribution and production of cassava. Likewise, concern about issues of global change has resulted in several books on the role of scales and global processes (Rosswall et al. 1988; Mounsey and Tomlinson 1988).

Scale is consequently a fundamental, albeit often unrecognized, variable in most resource management programs. This is true both in terms of scale as a mapping concept (i.e., units on the map per unit on the ground) as well as a management concept (i.e., local, regional, and national level management). Scientists have a poor understanding of relationships among different spatial scales. In terms of data analysis, management strategies that are sustainable at the field or farm level (e.g., the use of pesticides and inorganic fertilizers) may not be sustainable when applied to the watershed or region. In terms of data management, methods for switching scales easily are not well developed. Complex rules of generalization are needed to convert the computerized representation of a simple feature like a coastline to a larger scale, and it is extremely difficult to convert to a smaller scale because detail must be added (ACSM 1989).

This paper is built on the premise that scale issues (national versus community) are a major cause of tension between government planners and village users of public domain resources. The paper begins with a discussion of the "scale problem" and its relationship to data aggregation. The paper then reviews hierarchy theory and multiple scales, two methods (one theoretical and the other practical) for dealing with problems that span many scales. The application of these methods to community resource management programs is examined by way of an example. Finally the paper discusses methods for dealing with the conceptual and practical problems of changing scales.

THE "SCALE PROBLEM"

Geographers label the difficulties discussed above as the "scale problem." According to Harvey (1968) environmental processes contain a wide range of activities. Some of these processes contribute to a real differentiation at a local scale (e.g., tidal currents or community resource management). Others contribute at regional or national scales (e.g., tectonic activity or forest policy). Still others contribute at a worldwide scale (e.g., solar radiation activity or international timber trade). It has been generally agreed (although not always observed in practice) that different processes become significant to our understanding of spatial patterns at different scales.

Forman and Godron (1986) point out another aspect of the scale problem. As we progress from a fine scale to a coarse scale, do spatial patterns change smoothly and gradually or abruptly in a stair-step fashion? For example, "if we could view nature through an enormous camera zoom lens through which the focus is gradually and evenly changed would we see even changes in the clustering of individual organisms? Or would we observe patches within patches, that is, a patch at one distinct level of scale followed by a rapid change to another patch at a next level of scale?" For the most part we have no measure of the scale at which a particular process contributes most to the formation of a spatial pattern, and our notions regarding the scale problem remain intuitively rather than empirically based.

Map scale can be defined as the mathematical relationship between the size of objects as represented on maps and the actual size of the objects themselves. Maps drawn at small scales generally cover broad areas, show minimal detail, and the fraction expression has a large denominator such as 1/1,000,000. Maps drawn at large scales cover smaller areas, show greater detail, and have smaller denominators, such as 1/1,500. Unfortunately, large areas mapped at small scales are sometimes called "macro" and small areas mapped at large scales are called "micro." Thus macro, meso, and micro may refer to areas mapped at small, intermediate, and large scales respectively.

Broadly stated, small-scale information requires an aggregation of data while larger-scale information requires subdivision. Planners should choose data-aggregation levels that are appropriate for the phenomenon being studied. It is unnecessary and costly to use data that are more specific than the level of analysis requires. Relationships or classes contained within the data may require that the data be "smoothed" or aggregated in order to detect trends that could be lost in highly divided data. For example, a scale at which one can determine individual tree crowns may be useless for the study of vegetation associations because the pattern of the associations may be lost in the detail. On the other hand, if the available data are too general for the problem of interest, new data must be acquired, since aggregated data cannot always be disaggregated to achieve greater detail. From this standpoint, the more general the level of aggregation of data the more limited its potential usefulness to a variety of users.

Temporal scale must also be considered. Most data bases (spatial or aggregated) are concerned with current information. Planners often update these data bases by adding new information and deleting the old. This means that historical states are forgotten and that anticipated or forecasted futures cannot be treated. Because most natural resource events are dynamic and cannot be accurately represented by a static model, temporal scale is an important variable.

The term "scale" also refers to objects of distinct "relative size, extent or degree; for example projects done on a large scale" (Merriam-Webster 1981). This paper uses the term "spatial scale" to refer to the relative size of the landscape being discussed. For example, administrative regions such as local, provincial, and national governments imply small, medium, and large size spatial scales. Likewise, landscapes can be broken into field, farm, watershed, and landscape units; each unit is associated with a relative size.

While a map scale can be defined by a simple mathematical relationship, a more comprehensive definition of scale acknowledges that scales are mental concepts for describing reality. Mental concepts like scale can never completely capture the diversity and range of extremes found in nature. So in some sense, scale represents an epistemology problem—how do we know what we know? How well do words and language represent reality?

Regardless of definition, the "scale problem" arises from the fact that information is scale dependent. McCarthy et al. (1956) strongly emphasize the scale-dependent nature of information as follows: "Conclusions derived from studies made at one scale should not be expected to apply to problems whose data are expressed at other scales. Every change in scale will bring about a statement of a new problem, and there is no basis for assuming that associations at one scale will exist at another."

HIERARCHY THEORY AND MULTIPLE-SCALE APPROACHES

Hierarchy Theory

Hierarchy theory was developed by ecologists (among others—Koestler 1967, 1969; Simon 1962, 1969; Allen and Starr 1982) to provide a theoretical basis for dealing with scale problems. The theory asserts that a useful way to deal with complex, multi-scaled systems is to focus on a single phenomenon and a single time-space scale. By limiting the problem, it is possible to define it clearly and to choose the proper "system" to emphasize.

The following discussion of this theory is based on O'Neill et al. (1986) and O'Neill (1988).

Hierarchy theory begins by portraying a phenomenon of interest as a series of hierarchial relationships. Figure 1 shows the relationships between levels in such a system. The system of interest (level 0) is a component of some higher level (level +1). For example, if the object of study is an individual organism, in studying this object we discover reproductive structures and behaviors that are difficult to explain if attention remains limited to the single organism. Only by referencing the higher level, the population, can the significance of reproduction be explained.

The next step in studying the system is to divide level 0 into components forming the lower level (level -1). We study the level -1 components in order to explain the mechanisms operating at level 0. A mechanistic explanation ordinarily means that a phenomenon is the logical consequence of the behaviors and interactions of the lower level components.

Hierarchy theory thus dissects a phenomenon out of its complex spatio-temporal context. Our understanding of the phenomenon depends on referencing the next higher and next lower scales of resolution. Levels higher than +1 are too large and slow to be seen at the 0 level and typically can be ignored. Levels lower than -1 are too small and fast to appear as anything but background noise in observations of level 0. In this way, the theory focuses attention on a particular subset of behavior

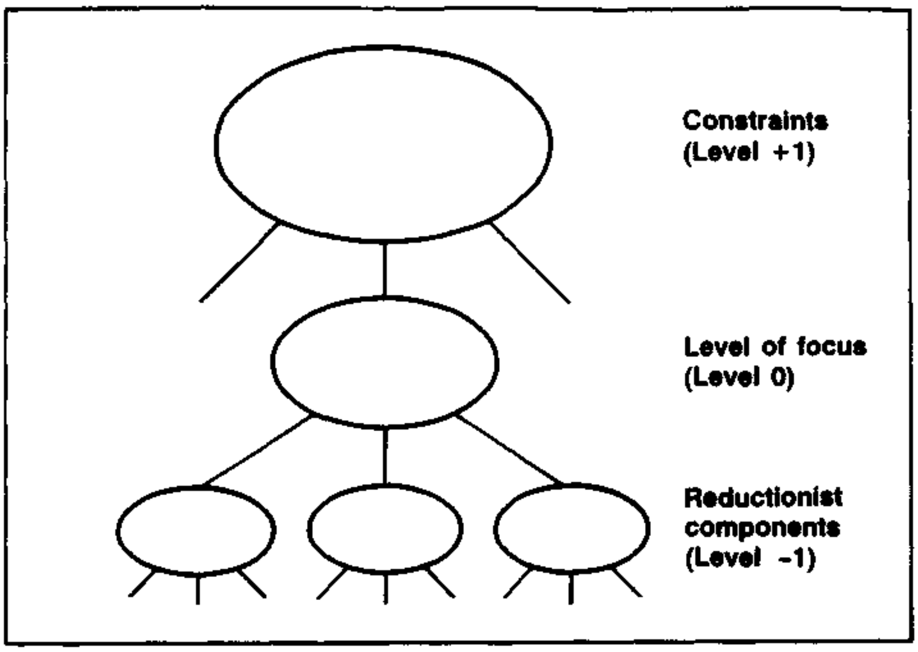

Figure 1. Schematic of hierarchy theory constraints. This approach may be applied to any level of scale (adapted from Dyer and Vinogrodov 1990:20).

and permits systematic scientific study of very complex systems. Starting from this introduction, let us try to apply hierarchy theory to community resource management problems.

Searching for the fundamental hierarchy. The theory recommends that we establish a hierarchy for studying complex systems. A caveat to this recommendation is that it is seldom fruitful to search for the one and only hierarchy because few single a priori criteria exists for developing this hierarchy. Instead, a number of different hierarchies may be used to address different problem areas. For example, consider dividing forest-use practices (level 0) into state variables (level -1). One might consider a breakdown according to managers to be individuals, households, communities, districts, provinces, and nations. This division permits one to emphasize spatial and bureaucratic differences among forest managers. Alternatively, one might choose to stress the products and not the users. These might include firewood, fodder, grazing, timber, and agricultural conversion. There is no good reason to force all problems into a single framework.

Searching for the fundamental level. It follows from the preceding that it is not fruitful to designate the one and only level to which all other phenomena must be reduced. While most ecologists agree that environmental systems are multiscaled, some still attempt to reduce all of ecology to a fundamental level such as the population or ecosystem. In terms of community resource management this is equivalent to trying to reduce all problems to the individual or household level. The phenomena of interest should determine the time and space scales emphasized by the researcher.

Translating principles between levels. Given that the system is scaled, what can we say about interactions between adjacent levels? In general it is not possible to transpose principles developed at one hierarchical level to higher and lower levels. Most concepts and models in ecology have been developed for a single scale. Yet this hidden assumption of scale is often ignored.

An example of transposition of scale was suggested by the example of pesticides and inorganic fertilizers. Farmers may use these products to increase the productivity of their crops. The farmer may see the beneficial consequences of these products in his fields and not be aware of the damage these products cause to lakes and downstream water bodies. Management strategies that are sustainable at the field or farm level may not be sustainable when applied to the watershed or region.

In terms of community resource management, an example of this criteria is provided by our experiences with pilot projects. Community workers chosen to work with pilot projects are carefully screened and given intensive training. In addition, these workers often have access to higher-level decision-makers and to resources that generally are not available. It seems logical that the lessons learned from these projects can be applied to regional and national programs. Numerous studies, however, have shown that without the tender-loving-care the pilot projects received, the expanded projects (broader scale) usually fail.

Effect of a higher level on a lower. O'Neill (1988) argues that one of the most powerful insights of hierarchy theory deals with the concept of constraint. Simply stated, higher levels set constraints or boundary conditions for lower levels. Aquatic production relationships provide an example of how higher level constraints can determine system behavior. In nutrient-limited, fresh-water systems, annual production is closely related to phosphorous loading. By knowing phosphorous levels, scientists can predict productivity without information about the species of phytoplankton involved in the process. Dynamics can be determined simply by knowing the higher level phosphorous constraints; detailed data on lower levels are not required.

We can attempt to apply this principal to community resource management. For example, national land-use policies set constraints for the successful implementation of community level projects. Policies which reward participants for cooperating with resource management programs have a chance for success. Policies that do not provide incentives for cooperation through recognizing the rights and obligations of resource users invariably fail.

Predicting the higher level from the lower level. Because higher levels set constraints or boundary conditions for lower levels, hierarchy theory states that higher levels can be used to predict the outcome of a given event on the lower level. It is more difficult, however, to move in the opposite direction. Some higher level properties are the sum or integral of lower level systems, many are not. Stated as a general problem, the influence of lower levels on the higher is known as the "aggregation problem." The problem is how to aggregate large-scale data in order to understand smaller scale (regional and national) problems. The problem of aggregation becomes important for three reasons. First, we wish to take advantage of available large-scaled information; second, it is sometimes insightful to seek explanations at much larger scales; and third, we need to understand lower level behavior to predict when unstable responses will occur.

This problem is of real importance because the most extensive information data bases are at large scales. For community resource management programs, the problem is how to utilize the data collected at household and village levels to make conclusions about the watershed, region, or nation?

Among the conclusions we can draw from hierarchy theory, the following appear to be useful for community resource management programs. First, the theory leads us away from the naive mistake of searching for a fundamental hierarchy or level of analysis. The theory suggests that we must consider different ways of structuring the data we collect and choose the hierarchy and level of interest according to the problem at hand. Second, the theory suggests that we can predict the influence of higher levels on lower levels. If we know something about a national or regional level phenomenon, we can predict the effect of that phenomenon on the local level. The opposite, however, is not true. Higher level phenomenon are not just the sum or integral of lower level systems. This conclusion suggests that we must carefully examine how we utilize the large-scale data we collect from individual households and communities to make generalizations about the broader region or nation. The theory also suggests that large-scales change so quickly as to be irrelevant to what happens at smaller-scales. Does this suggest, for instance, that in some cases we can ignore what is happening to the individual and concentrate on the household or community? Finally, the theory suggests the situation changes dramatically when the system becomes unstable. Now the large-scale dynamics are unconstrained and tend to change the system drastically. However, there is no theory available to predict exactly which large-scale processes will be most important.

Multiple-Scale Hierarchical Approaches

About the same time ecologists were developing a theoretical basis for dealing with scale problems, geographers and other land-resources specialists were developing a practical approach for representing environmental processes in a series of hierarchically arranged scales. Stone (1972) describes the multiple-scale approach as the division of data on a given topic or area into significantly different groups by the scales of information needed to describe, analyze, and present various distributions of data. The principal goal of this approach is to determine the number of scale classes to be used and the limits of each class. Scale classes depend on field observation, analysis of the data collected at various scales and careful comparison of these data with those available from other sources, and selection of the smallest scales wherein faithful generalizations may be made toward the initial objective of the study. Experience plays a major role in determining the amount of time and expense necessary for delimiting meaningful scale divisions; but the thrust of this approach is to develop a methodical procedure that guarantees consideration of all scales.

Stone argues (correctly in light of hierarchy theory) that it is a delusion to assume that large-scale study in the field can add up to small-scale conclusions in the office. Those conclusions must be reach through observation and mapping at smaller scales. Consequently, Stone recommends an hierarchy of scales minimally consisting of three levels such as regional (perhaps 1/500,000-1/200,000), sectional (1/200,000-1/75,000), and local (1/75,000-1/15,000).

Scientists from other natural resource related disciplines (e.g., ecology, botany, soils, and forestry) also favor a multiple-scale approach progressing from the general to the particular, in other words small-scale surveys followed by more detailed studies (Steele 1967; UNESCO 1973; and Druffel 1977). In addition to these studies which are directed to particular components of the land surface (disciplines), there is also a well-developed landscape science which attempts to find "naturally occurring" environmental units that can be recognized, described, and mapped in terms of the total interaction of the attributes under study (Naveh and Lieberman 1984; Forman and Godron 1986). Within these "natural units" there is supposed to be a recognizable, unique, and interdependent combination of the environmental characteristics of landform, geology, soil, vegetation, and water (Christian and Stewart 1968; Rowe and Sheard 1981; Bailey 1983).

Perhaps one of the best known systems for dividing a landscape into homogenous units is integrated land surveys

(Christian 1958). Integrated land surveys divide landscapes into units and systems. A land unit is an area of similar genesis as defined by topography, soils, vegetation, and climate. A land system is an assembly of land units that are geographically and genetically related. These concepts can be applied at any scale, and can be adjusted to the complexity of the landscape while maintaining their logical relationship to each other. Thus, working on a small scale, land units may represent gross land forms, such as mountains, valleys, alluvial plains, or plateaus, grouped according to their geomorphological relationships into land systems. On an intermediate scale these units may become the land systems, with the various slopes and aspects of the mountains or valleys, the various kinds of alluvial deposits of the flood plains, or the units of micro-topography of the plateau, as the land units. On a large scale further subdivision of parts of these units would provide the land units; and the survey would approach in nature a combination of a detailed ecological and soil survey, the land unit maintaining its character as a recurring topographic unit together with its characteristic soils and vegetation.

In spite of minor differences among the various landscape classification systems, a general parallelism is evident in the occurrence of distinguishable units of landscape and of ranking these in a hierarchy (Christian and Stewart 1968). These multiple-scale hierarchically arranged frameworks have emerged for a number of reasons. First, they make it possible to plan projects in an orderly and selective manner. Second, they serve as a guide to where and how widely the results obtained from investigations at one location or local experience may be expected to apply (thus solving the aggregation problem). If an agricultural experiment is conducted on a sample site, or a successful land use has been achieved, the results can be expected to apply to other occurrences of that site. However, different sites, even though apparently similar in many respects, must be suspected of responding differently until proved by trial to do otherwise.

Finally, a multiple-scale hierarchical framework provides a common basis of sampling for subsequent studies. Where data are to be collected for statistical, economic, education, health, biological, or other equally divergent purposes, there is an advantage if the geographic unit used for sampling is common to each.

The multiple-scale hierarchical framework provides a guide for addressing issues of scale (both temporal and spatial) and begins to answer specific questions. Answers suggested by the framework include the following. Because information is scale specific and data collected at one scale should not be used to make conclusions about phenomena occurring at different scales, it is usually necessary to use multiple-scales to describe any environmental process completely. The number of scale classes and the limits of these scales depends on the phenomenon of interest. While determining the appropriate scale classes forms a major subject of investigation, scientists from different disciplines recommend the use of three scales, for example large, intermediate, and small. As suggested by hierarchy theory, small-scale data can be used to make predictions and hypothesis about larger-scale events. The reverse, however, is not always true. Hence, when it is necessary to make small-scale conclusions based on generalizations from large-scale data, researchers should assess the accuracy of the conclusions carefully.

MULTIPLE-SCALES AND COMMUNITY RESOURCE MANAGEMENT

The insights we developed in the preceding discussion on hierarchy theory and multiple scales should be useful for dealing with scale issues in community resource management programs. The example reviewed in this section is based on a project in East Java, Indonesia. This project sought to identify relationships between land degradation and traditional land-use practices, and to help farmers identify methods for improving the performance of their existing land-use systems. Given these objectives, the project chose to use integrated land surveys to classify and map land units and rapid rural appraisal techniques to evaluate land-use practices.

The project began by manually identifying and classifying land units on Landsat images (1:250,000) (Fox and Suharsono 1986). Land units are areas where physical parameters, such as position in the landscape, slope, soil type, and depth, are similar (Christian 1958). These images provided a framework from which the project could choose sites for more detailed analysis. False-color infrared aerial photographs (1981, 1:30,000) were acquired for the three sites chosen from the Landsat images. Photo interpreters reclassified the original land units into more detailed groupings and mapped land cover and land dissection. Land dissection reflects past susceptibility to erosion processes and does not necessarily reflect current erosion problems.

The team then chose several villages as being representative of the land units mapped on the aerial photographs. Team members made numerous short visits to each of these villages in groups of two or three people. These groups used rapid rural appraisal techniques to collect information from farmers on land and land-use practices. Interviews focused on basic needs—food, fuel, water, shelter, raw materials for local industry, cash, savings/investment, and social production. The underlying assumption behind this approach was that land-use systems are organized so as to satisfy basic needs (Raintree 1987). Consequently to describe a system it is sufficient to identify the locally relevant forms of needs satisfaction (e.g., cassava and corn rather than rice, firewood rather than charcoal) and to describe the location, technology, resources, and activities involved in the production of the desired outputs (Fox 1989).

After completing the village studies, team members met with local farmers and discussed the physical, use, and socioeconomic characteristics of each land unit. This discussion resulted in the fifteen land units being reduced to three agroecological zones (large areas where physical properties, cropping patterns, and socioeconomic variables were relatively similar). For each agroecological zone, questions were raised about factors constraining current production levels or affecting land degradation.

An example of these agroecological zones is the limestone hills along the south coast of East Java (Semaoen et al. 1985; Fox and Suharsono 1986). These hills range in elevation from sea level to 500 meters. Shallow, infertile, alkaline soils overlay moderately sloping (10% to 30%) hillsides. Soil texture is often fine clay with many of the soils of the zone classified as vertisols. Groundwater is scarce since infiltration is low. A few small springs are found along cracks or joints in the surface.

The major crops grown include cassava and corn as well as fruit, nut, fodder, and firewood trees. Crop production is low because of limited soil fertility and severe water shortages during the long dry season. Farmers keep livestock, primarily cattle and goats, but these are of limited commercial importance. The farming systems found in these hills are fairly stable, as traditional crops are resistant to pest and disease vectors and the small degree of commercialization protects farmers from price variations.

Because of low productivity, farmers in this zone are reluctant to invest in soil-conservation measures such as benchterracing. Limited land capability and low cash incomes also severely constrain investments in commercial adventures. With the exception of limited use of inorganic fertilizers on staple crops, farm technology and socioeconomic conditions in this zone have been relatively static during the last decade.

Farm holdings in this zone are concentrated in small, owner-operated units, and absolute landlessness is low. Nonfarm employment growth has been slow. The refinement of limestone offers job prospects, but local deforestation constrains the necessary supply of firewood. Because of limited local economic opportunities, seasonal and permanent out-migration constitute the principal source of cash income in this zone.

The Agricultural Extension Service of the East Java provincial government used the findings from this project to design extension services that are sensitive to the physical environment as well as the cultural preferences of the farmers. This project demonstrates a useful method for dealing with scale in community resource management programs. As suggested by hierarchy theory and multiple scale mapping, the researchers mapped land variables at three scales each showing more detail then the previous one. Starting with the broad landscape, researchers used Landsat images to map small-scale units that were similar on the basis of geomorphology and vegetation. Intermediate-scale aerial photographs were then used to subdivide these units into more detailed land-units based on vegetation and land dissection. Finally, representative villages from each of the units identified on the intermediate-scale photographs were studied to develop a detailed understanding of natural and cultural features of land-use practices.

This project used small-scale data to classify the environment into relatively homogeneous units. These data provided a framework for choosing sites from which to collect larger-scale socioeconomic data. The data collected at the large-scale, however, were also used to redefine the small-scale units into three agroecological zones. Thus this project differs from hierarchy theory in that it suggests that the solution to the scale problem is a reiterative and not a simple linear process. This reiterative process begins with a general understanding (small scale) of a phenomena, moves to a more detailed (large scale) understanding, and then the knowledge gained in the large-scale study is used to redefine the original classification developed in the small-scale process.

There are of course problems associated with this method—primarily its subjectiveness. Different people define land units differently. Spatial statistics may be useful for testing the homogeneousness of these units and for quantifying the degree to which one land unit is related to another. A further aspect of this problem is found in the process of moving from smaller to larger scales, a theoretically endless process. At some scale everything is different from everything else. Where do researchers draw the line and say two things are similar or that they are different? Again spatial statistics may be useful in overcoming this problem. Reiteration is also problematic—how many reiterations are needed before we arrive at a generalization that best approximates reality? The subjectiveness involved in making these decisions may mean that solving scale problems is more an art than a science. By being aware of the steps involved and by using spatial statistics to quantify relationships between different units, researchers can begin to develop meaningful scale classes.

THE ROLE OF COMPUTERS

Computer software exists for representing complex spatial relationships; this software may assist planners to overcome many scale-related problems. The ability to change the scale of a display is one of the more immediately attractive features of computerized mapping systems or geographic information systems (GIS). The data contained in computer-generated maps, however, remain scale-dependent; in other words scale and spatial resolution are established by the scale of the input document. Complex rules of generalization are needed to convert the computerized representation of a simple feature like a coastline to a smaller scale, and it is extremely difficult to convert to a large scale in an appropriate way. As a result, computerized data bases must include multiple representations (multiple scales) of the same geographical feature (ACSM 1989).

The usefulness of computers lies not so much in the ability to change scales, but in the ease with which spatial patterns can be analyzed. For example, if we want to study a regional phenomenon we know intuitively to use small-scale data. But is 1:1,000,000 or 1:250,000 more appropriate for the phenomenon of interest? Computers and spatial statistics can play a role in quantifying the usefulness of different scales for studying specific patterns. Such methods do not remove scale as a variable (do not make data independent of scale), but they help researchers identify the scale at which a particular process contributes most to the formation of a spatial pattern.

Likewise, once we identify a scale for studying a given phenomenon there are different ways in which we can aggregate the data to form a classification scheme (soil, vegetation, etc.) or to model an event. A potential advantage of computerized mapping systems is that maps of terrain variables can readily be weighted and combined to display new or refined classification systems. Such flexibility is important because no single land classification is optimal for all applications. Scientists have applied many quantitative methods to land classification and it is beyond the scope of this paper to review these approaches. Rowe and Sheard (1981), for example, demonstrated the use of multivariate techniques to verify and refine map units initially recognized and delineated by theoretical considerations. Davis and Dozier (1990) demonstrated the use of mutual information analysis techniques to classify terrain based on digital maps of ecological variables.

Another advantage of computerized mapping systems is storage. Scientists find data stored in a "raw" unprocessed form more useful for a number of different purposes then data stored in a generalized format. But in the past data collected for making maps have been lost or have been unavailable for use by other scientists because of storage problems. Computers may help us to overcome this problem. For example, a soil scientist digs a number of soil pits in an area and describes their profiles. This information is used to map the soils of the area, but the actual information collected from the soil profiles is lost in the scientist's notes. A computerized mapping system makes it possible for the scientist to map the location of the soil pits and to save the details of the profile in an attribute file. Other scientists can then use this file to map soils according to their own needs. As computer storage capacities grow, researchers will be able to store increasing amounts of data in a "raw" or unprocessed format. This will make it possible for scientists to classify data in ways which more accurately reflect the phenomenon of interest. In this way computers can make a direct contribution to solving the "scale problem."

CONCLUSIONS

This paper examines the issue of scale in community resource management problems. Scale problems arise out of the fact that information is scale specific. Consequently, scientists recommend the use of multiple scales to describe any environmental process completely. This is true even with computerized mapping systems because the data contained in these systems remain scale dependent. Useful scale classes depend on objective and complete field observation, careful analysis at various scales in comparison with data from other sources, and selection of the smallest scales wherein faithful generalizations may be made. Experience plays a major role in determining useful scale divisions. Consequently, the process of defining scale classes remains more of an art than a science.

Hierarchy theory suggests that using small-scale data (upper level) to make predictions about large-scale events is more accurate then the reverse. Similarly, most geographers and land managers working with multiple-scale systems favor a stage-by-stage approach for obtaining land resource information, progressing from the general to the particular, in other words, reconnaissance surveys followed by more detailed studies. Scientists favor this approach because, among other reasons, the small-scale data provide a sampling framework for subsequent large-scale studies. No conceptual framework exists for the reverse process—integrating information of complex and detailed large-scale phenomena into simple and tractable models of small-scale systems (Woodmansee 1988). When it is necessary to generalize large-scale data to make conclusions at a smaller scale, extra effort must be made to assess the accuracy of the conclusions.

Computerized-mapping systems provide valuable assistance in analyzing similarities and differences among data bases within a given scale and between scales. This assistance makes it possible to begin to quantify the differences between different methods of defining scale classes. Another contribution computerized-mapping systems make to solving the "scale problem" is the ability to store extensive data sets. This capacity makes it possible to store original data and sampling points. Scientists working at a later date with different objectives can generalize these data to produce new information.

What do these conclusions mean in terms of the questions raised at the beginning of this paper about the usefulness of community resource management programs to national level planners? How generalizable are the results from Ciramaeuwah Girang to other villages in West Java or the rest of the Indonesia? Once the forest department has learned the lessons of this village do all future endeavors have to be equally labor intensive? What lessons learned from other parts of Indonesia can be applied in Ciramaeuwah Girang? Hierarchy theory and multiple scales suggest that the answer to these questions lies in collecting information at different scales. A reconnaissance level survey provides a guideline for dividing the landscape into classes of similar climatic and geomorphological genesis. A mesoscale survey divides broad landscape classes into units reflecting structures such as watersheds or administrative boundaries. Finally, microscale or village level studies provide essential information for understanding specific resource management problems within given communities. The knowledge gained from a specific community can only be applied to other communities if the researcher has already developed a small-scale classification of the broader region. Generalizations can be made among communities within the same class, although these generalizations should be examined closely.

In terms of analysis, hierarchy theory and multiple-scales suggest that data should be collected and examined at different scales. Scientists should study the effects of farm-level management strategies (such as the use of pesticides and inorganic fertilizers) not only on the farm but also at the broader scale of the watershed and the region. Likewise, planners should examine the effect of national policies (such as price, land tenure, and forest management) not only from the national perspective but also at the finer scale of the village and individual farmer. When scientists and planners recognize scale for the fundamental role it plays in resource management programs, terms such as top-down and bottom-up become meaningless. Because information is scale-specific, it is necessary to use multiple scales to describe any environmental process completely. Both top-down (small scale) and bottom-up (large scale) approaches are necessary for formulating and solving resource management problems. These conclusions apply whether the phenomena of interest are community resource management projects or global ecological processes.

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