Scale. Scale is the spatial, temporal, quantitative, or analytic dimension used to measure and study objects and processes. Two important components of scale are extent and resolution. Extent is the magnitude of a dimension used in measuring, whereas resolution is the precision used in this measurement. For example, if a map consists of square **pixels**, then the amount of land portrayed by the collection of pixels determines the extent, and the size of the individual pixels determines the map's resolution. In this case, the length of the side of the pixel is the measurement of the map's resolution, which is also known as the grain.

Categorical scale is the level of detail of the categories in an analysis. For example, in classification of land cover, a hierarchy may be defined in which many detailed categories can be aggregated into fewer coarser categories, which can be aggregated further into even fewer, more general categories.

The word scale frequently causes confusion because it has many meanings. The most common source of confusion derives from the fact that some

scientists use simple descriptors such as "small" and "large," while they simultaneously fail to specify which version of the definition of scale they are using. If a scientist uses the word scale to mean "extent," then "small scale" means a small study area. If a scientist uses scale to mean the ratio between the map and the ground (e.g., 1/1,000), then "small scale" means a large study area for a given size of paper map. If a scientist uses the word scale to mean resolution or categorical detail, then the size of the scale is independent of extent. There would be less confusion if scientists used the adjective "fine" to describe the small grain of highly detailed resolutions and "coarse" to refer to large grains of less-detailed resolutions. The adjectives "small" and "large" should be reserved to describe extent.

The operational scale is the scale at which a certain process (e.g., a land use decision) manifests on the landscape. Land use and cover changes are the results of many interacting processes. Each of these processes operates over a range of scales in space and time. Land-use decisions are made at different levels of social organization (e.g., the individual or community level). Level refers to level of organization in a hierarchically organized system and is characterized by its rank ordering in the hierarchical system. Other examples of levels include the organism, ecosystem, landscape, social system, nation, and globe. If the operational scale does not correspond with the scale of the data, then the scientist might not be able to determine the correct processes. **Land-use systems** rarely produce a single scale that can be regarded as correct or optimal for measurement and prediction, because landscapes usually demonstrate many interacting processes. An optimal scale of analysis for a specific data set might exist where predictability is highest; however, that scale will not necessarily be the same for other analyses. Therefore, it is desirable to determine the scale of the analysis from a careful examination of the phenomenon, rather than using *a priori* scales of observation.

The interaction of processes at various scales and the mismatch between operational and data scales are common. These can cause results of empirical analysis of land-use change to be sensitive to the selection of both extent and resolution. In cases where an investigation attempts to use data that are readily available, the extent and resolution of the analysis are sometimes determined by factors that are independent of the phenomenon. For example, if the phenomenon of interest is **deforestation**, then the available data are frequently in the form of satellite images, which are available in pre-determined extents and resolutions that are functions of the path and sophistication of the satellite used to create the image. If the scientist adopts the satellite image as the study area, then both the extent and the resolution are dictated by the format of the available data, not the phenomenon. Scientists are developing tools to measure the degree to which changes in scale influence the analysis of the phenomenon. This challenge is closely related to geography's famous and unsolved "Modifiable Areal Unit Problem," which states that statistical results are sensitive to changes in the areal unit. Numerous examples in land-use change research have indicated that the analysis of the relation between land-use change and its **driving forces** should not be restricted to a single scale. Multiscale and multilevel techniques are better able to unravel the complex interactions and **feedbacks** over scales that determine the functioning of the

land-use system. Scale remains one of the major challenges of geographic analysis, and is consistently ranked as a top research priority by the University Consortium on Geographic Information Science.

See also: **Auto-Correlation; Environmental Change; Integrated Assessment; Land Cover Classification System; Land-Use History; Mediating Factor; Millennium Ecosystem Assessment; Pattern Metrics; Pixelizing the Social; Remote Sensing; Socializing the Pixel; Validation; Vulnerability.**

Further Reading

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