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Recent Experience in Mapping Land Cover from AVHRR Data: People's Republic of China Test Sites**

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RECENT EXPERIENCES IN MAPPING LAND COVER FROM AVHRR DATA: PEOPLE'S REPUBLIC OF CHINA TEST SITES

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INTRODUCTION

There are well-documented needs for small-scale (1-km) land cover data for use in national to global environment assessments [1]. While there is general acceptance that 1-km data from the Advanced Very High Resolution Radiometer (AVHRR) are the most appropriate imagery for mapping land cover over large areas, the practical understanding of the consistency of results in different landscapes is limited. For AVHRR to be used effectively throughout the globe, it is necessary to understand the environmental and technical factors that influence the quality of results. To better understand these factors, researchers from the People's Republic of China (PRC) National Bureau of Surveying and Mapping (NBSM), the U.S. Geological Survey (USGS), and the University of Nebraska-Lincoln mapped land cover for two test sites in China. This collaboration was conducted as part of a formal protocol between the NBSM and USGS.

STUDY SITES CHARACTERISTICS

The two sites, in the north central and south east regions of the country, differ in climate, vegetation, and land use intensity. The north central site encompasses an area from 31 N to 41 N and 101 E to 115 E. It includes all or portions of Shanxi, Shaanxi, Hubei, Henan, Gansu, Sichuan provinces and the autonomous region of Inner-Mongolia. Three physiographic regions can be identified in the area: a temperate desert and semi-desert environment in the north west, a mosaic encompassing the Loess Plateau, a series of mountains and inter-mountainous basins, and several fluvial plains in the east, and the Tibetan Plateau in western Sichuan province. The south east site lies between 24 N to 28 N and 108 E to 114 E, including portions of Hunan, Guangxi, Guangdong, Guizhou, and Jiangxi provinces in southeastern China. This region is in the subtropical monsoon climate zone, and is an area heavily influenced by cultivation and socio-economic development.

DATA

Primary data used in this study are the NOAA AVHRR 1 km Normalized Difference Vegetation Index (NDVI) composites for the 1992 growing season. The NDVI composites were compiled by the USGS EROS Data Center [2]. Seven monthly composites (from April through October) were acquired initially for the two study areas. Because of excessive cloud-contamination in some monthly composites, a decision was made to combine six monthly composites into three bi-monthly composites for the north central site (i.e. April-May, July-August, and September-October). For the same reason, two monthly composites (July and October) for the south central site were not included in this study. Besides NDVI data, a digital elevation model (1:4,000,000) of the study area was provided by NBSM, and a digital soil database was acquired from the Remote Sensing Center, Beijing Agricultural University, China. An atlas of China land use (1:1,000,000), compiled by the Institute of Geography, Chinese Academy of Sciences in 1980, was referenced to aid land cover interpretation [3].

LAND COVER CLASSIFICATION PROCEDURE

The land cover classification procedure utilized in this experiment drew from experience by land cover characterization research conducted by the USGS EROS Data Center and the University of Nebraska-Lincoln [4]. Several steps were taken to derive seasonally-distinct land cover regions from the NDVI time series and other ancillary data. The initial classification using NDVI composites was accomplished with an unsupervised clustering algorithm and minimum-to-mean-distance classifier implemented in the Land Analysis System (LAS) image processing package. More than eighty clusters were generated for two test sites and their statistics were computed for further analysis.

RESULTS AND ANALYSIS

<u>Class labeling and refinement using ancillary data</u>--Temporal NDVI profiles were examined for initial class labeling in relating some clusters to major land cover types (e.g., desert and semi-desert steppe, cropland, grassland, and forest). However, some clusters could not be readily labeled based on NDVI profile alone due to spectral-spatial confusions among land cover types. The confusion was primarily related to variations in vegetation phenology and topographic feature. Among the mixed classes, two types of clusters were distinguished: 1) clusters composed of two or more cover types coexisting within a similar environment, and 2) clusters corresponding to two or more cover types with each type occurring at different locations. Clusters of the second type were refined using ancillary data. For instance, cluster 9 in the north central site occurred in two geographic regions: the east section with predominant lowland agricultural land use, and the southwestern section located in the Tibetan Plateau. Accordingly, the cluster was split into dryland cropland and subalpine meadow based on elevation and geographic location. Cluster 25 covered both paddy fields and forest. The cluster was split by

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intercepting the class with paddy soil categories. Cluster 28 contained plain irrigated cropland, terraced paddy and slope grassland. Based on documentation of local environment [3], most plain cropland is located below 600 meters, the terraced paddy in between 600 to 1500 meters, and slope grassland above 1500 meters. Thus, digital elevation data were used in this case to split cluster 28 into three classes. A similar process was also applied to the south east site in post-classification.

The final classification yielded 26 distinct land cover types for the north central area and 16 classes for the south east site. Table 1 lists 18 major land cover categories identified from this study.

Table 1. Land Cover Classes

Class ID	Class Label
1	irrigated cropland (paddy)
2	irrigated dryland cropland
3	non-irrigated cropland
4	coniferous forest
5	deciduous forest
6	mixed forest
7	sparse woodland
8	firewood and bush
9	meadow
10	steppe
11	alpine and sub-alpine meadow
12	slope grassland
13	sandy desert
14	bare ground/sparsely vegetated land
15	woodland/grassland
16	woodland/cropland
17	woodland/bamboo/grassland
18	tree crop/woodland

Effect of cloud on classification--The presence of cloud and atmospheric haze caused some problem for the classification. Approximately one third of the total clusters (15 out of 46) in the south east site were affected by clouds. Low NDVI values (<0.15) were recorded for some forest area during the mid-growing season. For instance, class 25 is coniferous forest which is the same cover type as class 26 and 29; yet its NDVI of August is significantly different from the latter two classes (0.46 versus 0.15, 0.10). The severe cloud-contamination on the NDVI is related to the monsoon rainy season of the area, which can last for long period during growing season. This problem is a recurring issue for large area land cover mapping using AVHRR data and needs to be further addressed.

Heterogeneity of land cover--In general, broad land cover patterns were adequately defined in both test sites. However, identification of detailed land cover types was uneven, especially for the south east test site. The classification of this area was comprised of a significant number of mosaic categories that often included disparate land cover types. This was the result of extremely complex and fragmented land cover patterns resulting from topographic influences and intense human activity. The heterogeneity of land cover in this area necessitates the inclusion of several mixed (or mosaic) cover categories in the final classification (Table 1). For the northern site, the mixed land cover types include cropland/grassland, cropland/woodland, cropland/woodland/grassland. The south east site identified several unique mixed cover types (grassland/tree-crop, forest/bamboo/grassland), in addition to those found in the northern site.

Special land cover classes--The identification of small paddy fields and bamboo forest in the south east site was a challenge. These cover types are often spectrally and spatially mixed with others, and therefore, are difficult to separate. In some area, the difficulties can be eased by using ancillary data. In eastern Hunan province, for instance, paddy fields were satisfactorily extracted using slope and soil data (slope < 1 degree, and soil type). One extensive bamboo forest area in this site was separated from other mixed grassland/woodland using elevation data. In contrast, other bamboo mixed classes were not separable due to a mixture with forest and grasslands. The inconsistency in occurrence of location and highly interspersion of those cover types make them difficult to identify.

Smoothing process--Because of the complex land cover patterns of the south east test site, the final land cover classification was further processed using a smoothing procedure developed by NBSM scientists. The smoothing process was based on mathematical morphology, noise cleaning, and region/neighborhood analysis. This method effectively generalizes the classification and allows the dominant regional land cover to be expressed. This procedure also facilitates the inclusion of the results into geographic information systems.

DISCUSSION AND SUMMARY

This experiment has demonstrated that large area land cover mapping in north central and south east China using NOAA AVHRR 1-km NDVI composite data is feasible. Qualitative comparison of the results with the 1:1,000,000 China land use/cover maps [3] suggested that major land cover types can be adequately mapped with AVHRR NDVI data aided by digital elevation model, soil database and other ancillary data. Several observations were made with regard to what has learned from this experiment.

The characteristics of the physical environment and land use practices of the two test areas had significant impact on the classification outcome and on post-classification strategy. For the north central site, distinct spatial differentiation in local climate, soil properties, and topography allows major land cover types to be readily identified on the classified image. In contrast, the extremely complex and fragmented land cover/land use patterns of the south east site imposed considerable difficulties in identifying certain land cover classes. In some cases, the same land cover types with different temporal NDVI were classified into several groups due to variation in plant phenology, geographic location, and local topography. Conversely, some different land cover types had similar NDVI temporal profiles and were classified into a single cluster. Under such circumstances, availability of ancillary data and information on the local environment become essential in formulating post-classification strategy in order to refine class labeling. In this study, the digital elevation model and soil data base were particularly useful in post-classification stage.

The effects of cloud-contamination on land cover classification has been an issue addressed by researchers. In the present study this problem was particularly noted in the south east test site, a region with subtropical monsoon climate. Because the growing season of the area corresponds to the rainy season, even the monthly NDVI composites are not adequate to generate usable data for some months. Research on development of robust cloud screening methods and techniques for mitigation of cloud-contamination for AVHRR data are warranted. Until such methods are available, the quality of the land cover mapping in the extreme cloud-prone regions may be necessarily compromised.

This study also suggests a need for developing an appropriate hierarchy for describing highly mixed land cove types. The mosaic and extreme fragmented land cover patterns in southeastern China is the rule rather than exception. The diverse land use patterns and frequent changes in spatial composition of cover types demand careful considerations in class labeling and post-classification as well as presentation of the results.

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