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Mapping China's New Agricultural Lands

Landsat data in image and CCT formats have been used to determine new agricultural land developments and cropping patterns in Northeast China.

Introduction

Landsat has provided extensive new opportunities for studies of foreign areas where accurate, contemporary spatial data are unavailable or difficult to obtain. China is such an area, and the goal of this research has been to map land use and assess agricultural land reclamation efforts and cropping practices in one portion of Northeast China. In order to appreciate the value of data from a sensor system such as Landsat for this purpose, however, some knowledge of the historical development of this large and remote area, formerly known as Manchuria, is required (Figure 1).

The 19th and 20th century settlement of the Northeast contrasts with the long history of the densely populated areas of eastern China and in ways is analogous to westward expansion in the United States during the same period. In the late 19th century, for example, the Chinese abolished all restrictions on migration and settlement in order to attract land hungry peasants and to consoli-

KEY WORDS: **China; Computer compatible tape;** Corn; **Crops; Farms; Kaoling; Landsat; Land use; Maps; Mechanization;** Millet; **Rangeland;** Soybeans; **Spectral reflectance; Spring wheat; Wetlands**

ABSTRACT: Landsat image data in photographic and computer compatible tape (CCT) formats was employed to map land use and identify crops in the Nun River Basin of Northeast China, a study area of approximately 184,500 km^2. Examination of 27 Landsat scenes recorded between 1972 and 1976 disclosed that approximately 15,300 km^2 of rangeland and wetland have been converted to new agricultural land in an attempt to expand agricultural production. These new lands are characterized by large geometric field patterns designed to accommodate mechanized farming practices.

Three major crop categories — soybeans, corn/millet, and harvested wheat/millet — were identified on two large farms by a combination of manual and unsupervised/supervised computer assisted classification techniques undertaken in conjunction with crop calendars and spectral reflectance data. Based on studies of the farm areas and examination of cropping patterns throughout the Nun River Basin, it appears that food crops such as spring wheat and corn have replaced soybeans, kaoliang, and millet as the principal crops in the Northeast. In this study the absence of definitive ground truth was overcome by the correlation of Landsat image data with available maps, reports, and other supplementary information to provide a basis for an objective evaluation of China's land development policies. It is suggested that the remote-sensing techniques employed in this study are applicable to other foreign areas of geographic interest.

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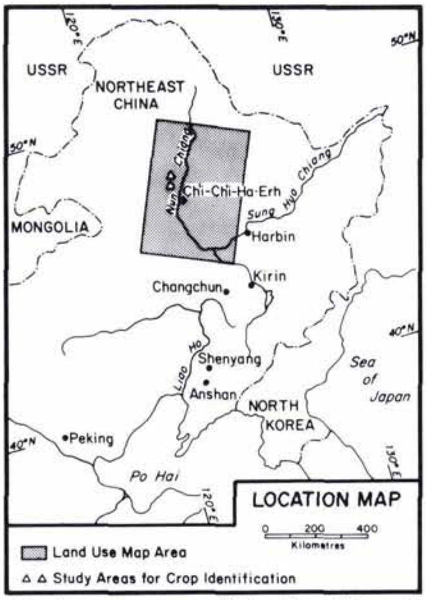

FIG. 1. Location map of the Nun River Basin study area in Northeast China.

date control of the region. As a consequence of this policy, the land area under cultivation increased rapidly to correspond with a rise in population from approximately 10 million in 1900 to over 30 million by 1930. This move by the Chinese was also undertaken to offset Russian influence stimulated by development of the Chinese Eastern Railway (1897-1901) connecting Ch'i-ch'i-ha-erh and Harbin with the Russian cities of Chita and Vladivostok, and the construction of the South Manchurian Railway (1901-1904) linking Harbin with the port of Darien (South Manchurian Railway Co., 1922; Kinnosuki, 1925). In 1931 the Japanese occupied Manchuria and imposed restrictions on Chinese immigration. As a consequence the population growth slowed, and Chinese agrarian settlement was checked until the termination of Japanese occupation in 1945.

By 1947 the Chinese communists had established control of much of the Northeast. This region is now viewed as one of the last remaining frontiers in which to increase agricultural production for China's rapidly growing population of approximately 950 million, and vast tracts of comparatively level and potentially fertile land remain unused for agricultural purposes. Aside from the cold and comparatively dry climate, the most serious problem has been the poor drainage and boggy character of the land. Consequently, substantial reclamation efforts are reported to have centered on the drainage of land previously unsuited for agriculture and on the development of large farmlands/field patterns compatible with mechanized farming practices (i.e., the "new lands"). Other reported developments related to agriculture include the establishment of windbreaks, the construction of reservoirs, dikes, and irrigation systems, the initiation of afforestation projects, and the significant alteration of cropping practices (Shabad, 1972; Economic Guide Publisher, 1976).

The extent and distribution of these agricultural developments cannot be determined from available literature, and the overall success of Chinese land reform/reclamation practices is a subject of considerable speculation. Welch, Pannell, and Lo (1975) previously mapped the southern portion of the fertile Northeast Plain from Landsat images and demonstrated that Landsat data can be used in conjunction with available reports, aerial photographs, and maps to prepare an objective and up-to-date assessment of land use practices of an inaccessible Asian study area such as China. In this paper the methodology is further developed and extended to the Nun River Basin, a rural and remote study area which is reported to have undergone significant changes in recent years (Central Intelligence Agency, 1971; Shabad, 1972; Economic Guide Publisher, 1976). Topics which will receive particular attention include the mapping of current land use patterns, the delineation of new agricultural land, and the identification of crops from Landsat data in photographic and computer compatible tape (CCT) formats.

THE NUN* RIVER BASIN

Bounded by the forest-covered Khingan Ranges (with elevations reaching 1500 m), the Nun River Basin study area occupies approximately 184,500 km^2 in Heilungkiang and Kirin Provinces of Northeast China as shown in Figure 1, an area equivalent to North Dakota. The Nun River splits the study area in half, and poorly drained wetlands consisting of bogs, ponds, and saline marshes occur with increasing frequency as relief diminishes from north to south. The drainage of these wetlands is one of the main

(Text continued on page 1221)

* Nun (River) is romanized Nen (River) in the Chinese *Pin-yin* system. Nen is also a variant spelling of Nun in the Wade-Giles system mainly employed here. However, Nun is a commonly used, conventional spelling for the character (4765 in *Mathews Chinese-English Dictionary*), and thus was selected for use here.

LAND USE AND NEW LANDS OF THE NUN RIVER BASIN, NORTHEAST CHINA

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Nine land use classes were employed to compile this map of the 184,500 km^2 Nun River Basin study area. A detailed description of each of these classes is presented below in a sequence which corresponds with the map legend. The area of each land use class in km^2 is given in the accompanying table.

Wetland

Grassy marshes and bogs are distributed on the plains, and forested swamps are found in the mountain valleys. On the map large stretches of wetland are distributed in the central part of the basin and along the Nun River flood plain. These wetlands are the result of poor drainage and a climate that is characterized by concentrated monsoon (summer) rainfall and low evaporation. It is recorded in the local county histories that transportation across the countryside is extremely difficult during the rainy season. Large-scale reclamation of wetlands can be detected in numerous localities on Landsat MSS images. As an example, a 60-km ditch has been constructed to drain the area east of Ch'i-ch'i-ha-erh. The accuracy of classification for this category is difficult to ascertain since a large percentage of the wetlands is used by farmers as pasture during the dry periods of the year and possibly could be classified as rangeland.

Rangeland

Steppe, scrubland, and grassland are collectively classed as rangeland. Rangeland is widely dispersed with some large stretches located in the southwest portion of the study area. Much of the original rangeland is being converted to cropland, and, with the exception of areas characterized by rough terrain and/or poorly drained alkaline soils, this effort is expected to continue.

Forest

Coniferous forests dominate the Greater Khingan Range along the west and north margins of the study area. The forest lands are easily identified by their bright red color on Landsat color composites recorded between June and mid-September. Images obtained in winter and early spring are not suited for forest classification because of snow cover in the mountain areas.

Water

Lakes and reservoirs are numerous. A large number of lakes have been drained in recent years and their borders are still recognizable on the Landsat images. It appears that drained lakebeds and playas are being reclaimed for cultivation, and additional reservoirs constructed for irrigation and flood control. Comparisons of images recorded at various times of the year indicate that the areal extent of some lakes and reservoirs fluctuates by a factor of three to four.

Urban or Built-Up Land

Urban land is comprised of areas of intensively used space with much of the land covered by structures. The small-scale and limited resolution of the Landsat images generally restrict the identification of urban areas to those with populations greater than 50,000. Because most of the small Chinese cities are very irregular in shape with mixed land uses at their margins, boundaries must be generalized. A comparison of the Landsat images with 1:250,000 scale AMS sheets of the same area published between 1950 and 1954 indicates that most cities have expanded and that some new cities have been established within the Greater Khingan Mountains. Fu-la-erh-chi, for example, has roughly tripled in area to 34 km^2 and T'ao-an doubled to 18 km^2. Highway and road networks have increased significantly since the early 1950's; however, the difficulties of delineating road networks on Landsat images have precluded their inclusion on the map. Railroads have also increased, and it was possible to plot a reasonably complete rail net by correlating Landsat images with existing maps and aeronautical charts.

New Agricultural Land

New agricultural lands are reclaimed from rangeland, wetland, rough terrain, or dry/salty soils. Tremendous efforts are required to improve the physical environment, including the construction of drainage ditches and irrigation channels, planting of windbreaks, and improvement of soils. In general, new land can be subdivided into two categories: a) land reclaimed by state, public security, and/or military farms; and b) land managed by local communes around their individual settlements.

The lands reclaimed for state and military farms can be identified and mapped from Landsat images using the following criteria:

1) uniform geometric pattern—most of the recently reclaimed cultivated lands are easily recognized by large, rectangular field patterns.
2) large field size—field sizes greater than 20 ha indicate mechanized farming practices.
3) location—large tracts of new agricultural lands are located in areas of reclaimed marsh, alkaline soil, or rough terrain. They are normally detached and isolated from "old" croplands.
4) signature differences—a slight reflectance difference always occurs between new and old farmland areas, probably due to variations in the soil conditions.
5) comparison with maps—villages, farm roads, and small local towns are recorded on the 1:250,000 scale AMS sheets published during the period of 1950-1954. Comparison of the AMS maps and Landsat images permits the identification of newly developed farmlands in areas depicted as wetlands and rangelands on the maps.

The new agricultural lands reclaimed by local communes generally cannot be reliably distinguished from older farmlands on Landsat images, and it has been necessary to group commune developed new agricultural lands in Extensive Field Cropland on the land use map. Consequently, the calculated total area for new agricultural land (15,300 km^2) is a very conservative estimate of the agricultural transformations which have occurred in the Nun River Basin.

Clear-Cut/Burned Land

Railroads and roads have been built into the forests to support lumbering or mining activities. In the more accessible regions the forests have been cleared and converted to new agricultural land. Large patches of clear-cut and burned areas can be identified on the Landsat MSS images by their dark tone.

Intensive Market Garden

Intensive market gardens of vegetable crops surround the outskirts of the larger cities and reflect the goal of Chinese planners to make the cities self-supporting. On summer false-color composite images the market gardens appear as bright red fields forming distinct rings around cities such as Ch'i-ch'i-ha-erh, Fu-la-erh-chi and T'ao-an. These rings facilitate the detection and identification of urban areas.

Extensive Field Cropland

Extensive field cropland is farmland which has been traditionally cultivated for soybeans, corn, kaoliang, wheat, and millet. This class is readily identified by distinct field patterns oriented in a north-south or northwest-southeast direction. Individual fields average one to two km in length and 200 to 400 m in width (approximately 20 to 40 ha per field). The regular farm patterns and relatively large field sizes indicate that mechanized agricultural equipment is being employed.

Areas of the Various Land Use Classes

Category	Area in km^2	% of Nun River Basin Study Area
Wetland	26,500	14.4
Rangeland	25,200	13.7
Forest	46,400	25.1
Water	1,330	0.7
Urban	165	0.1
New Agricultural Land*	15,300	8.3
Clear-Cut and/or Burned Land	2,325	1.3
Intensive Market Garden*	785	0.4
Extensive Field Cropland*	66,500	36.0
Total Area	184,505	100.0
Total Farmland*	82,585	44.8

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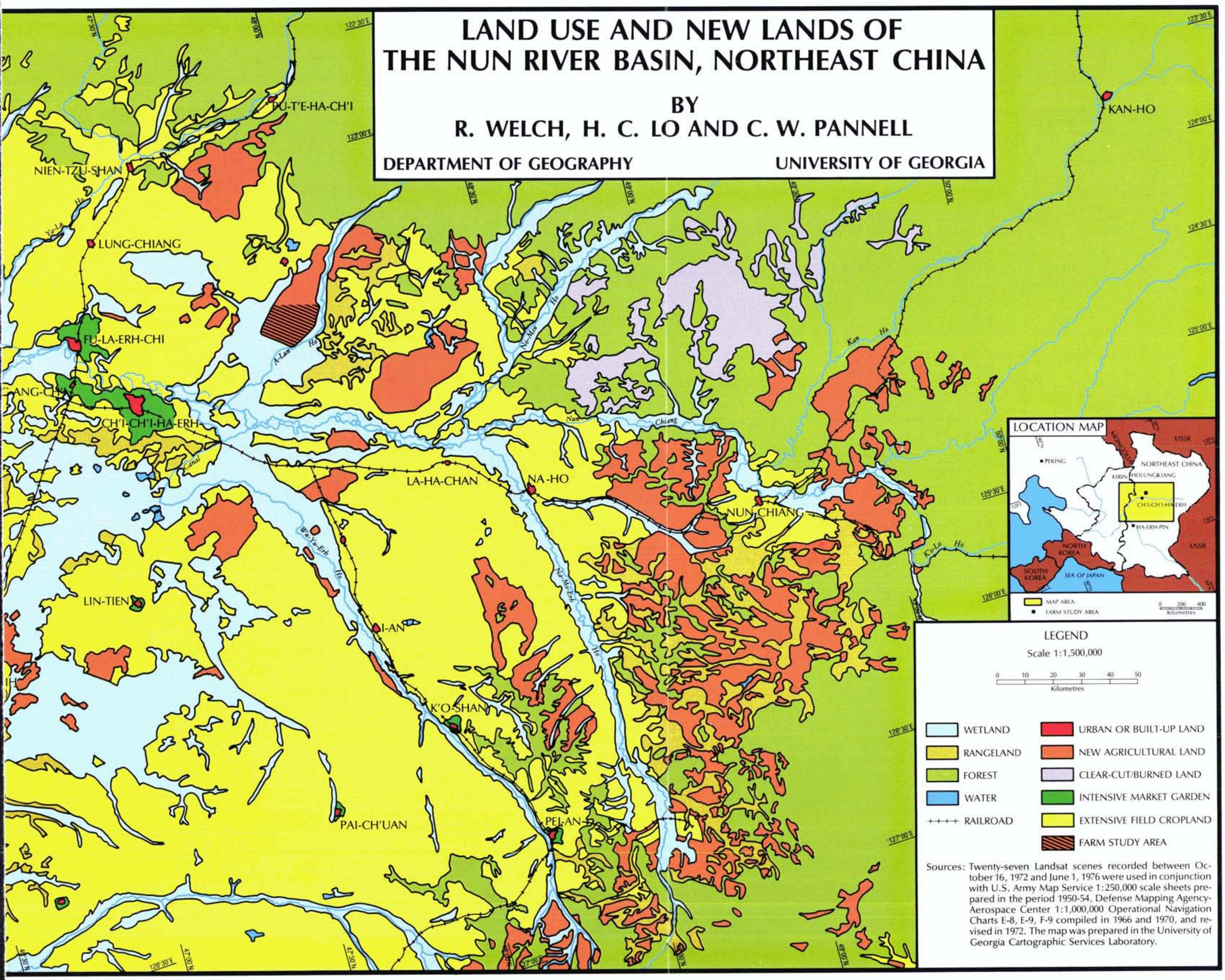

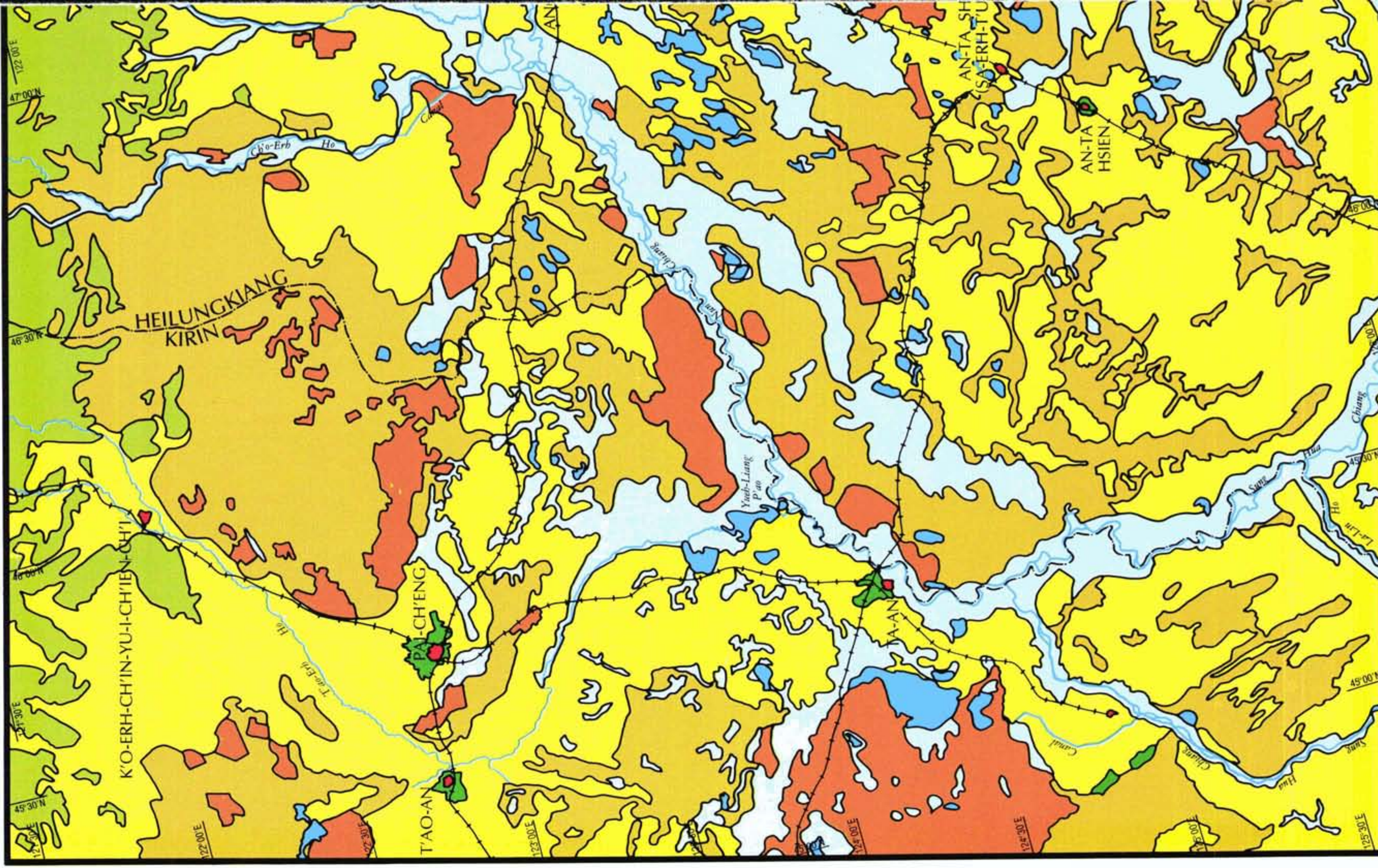

HEILUNGKIANG
KIRIN
Ch'o-Erh Ho
Canal
AN-TA HSIEN
K'O-ERH-CH'IN-YU-I-CH'IEN-CH'I
PAI-CH'ENG
T'AO-AN
TA-AN
Nun Chiang
Yueh-Liang P'ao
T'ao-Erh Ho
Sung Hua Chiang
La-Lin Ho
Canal
47°00'N
46°30'N
46°00'N
45°30'N
45°00'N
122°00'E
121°30'E
122°00'E
123°00'E
124°00'E
124°30'E
125°30'E

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challenges to land reclamation and agricultural production. Only on the older farmlands which occupy higher ground are agriculturally productive chernozems and brown soils well developed. A single major city, Ch'i-ch'i-ha-erh (estimated population of 500,000), is located near the center of the study area.

Prior to 1947 the farms of the Nun River Basin were generally small and probably averaged less than 5 ha. A large percentage of the farmland was allocated to the most important cash crop, soybeans, with kaoliang (grain sorghum) and millet the principal food crops. Spring wheat was limited to small areas in the far north.

With the establishment of communist government control in 1947, colonization resumed and large tracts of wasteland were converted to farmland. Between 1953 and 1975, nearly 200 large-scale and over 700 small-scale state farms were established in the Nun River Basin and along the lower reaches of the Sungari River. By 1975, 470 reclamation areas had been established in Heilungkiang Province alone and newly reclaimed land in this province was reported to exceed 13,000 km^2 (Economic Guide Publisher, 1976).

The land reform and reclamation movements also have included the formation of communes and the consolidation of older, fragmented land holdings into larger units better suited to the adaptation of mechanized agricultural procedures. By 1975 virtually all state farms and approximately 80 percent of the communes were employing mechanized techniques for plowing, seeding, and harvesting (Lo, 1977). Cropping practices are reported to have changed with soybean production declining in favor of spring wheat and corn. Kaoliang and millet also continue to be important (Liao-ning tieh-ling College of Agriculture, 1976).

Land Use Map of the Nun River Basin

A map of the Nun River study area at a scale of 1:1,500,000 was produced from manual interpretations of Landsat MSS images in bands 5 and 7 to portray current land use and the spatial distributions of new land developments (map insert). Twenty-seven Landsat scenes were obtained for the study area. Of these, 15 scenes were recorded during the growing season of April to September, and 12 scenes in the winter months of October to March (Figure 2). Seventy percent of the study area was covered by imag-

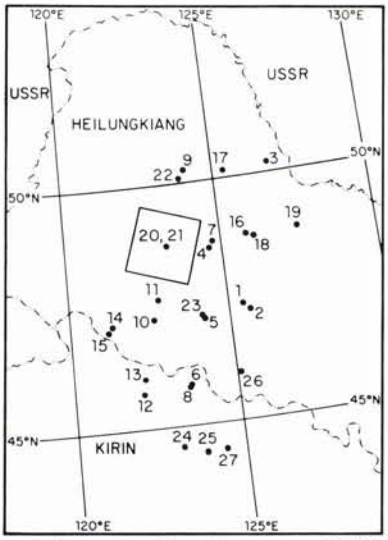

Fig. 2. Index map of Landsat scenes (1972-76) of the study area.

ery from three or more dates, facilitating the analysis of land use patterns and crop types.

Landsat positive transparencies in 70 mm format were placed in an I^{2}S 6040-PT Mini-Addcol Viewer and projected on the viewing screen as false color composite images at 1:500,000 scale. Overlays of the viewing screen permitted the direct transfer of land use/land cover information in the nine classes described on the map, most of which are shown in photographic format in Figure 3. Subsequent registration of overlays from different dates facilitated the analyses and permitted the preparation of master overlays portraying an aggregate of the land use information. The master overlays were then pieced together as a mosaic to produce a land use map at 1:500,000 scale of the entire study area. Points common to adjacent overlays were used to control the assembly and, where necessary, a Saltzman overhead reflecting projector was employed to compensate for slight scale variations in the individual overlays. Throughout the analyses reference was made to available literature and maps.

The final cartographic compilation was undertaken by The University of Georgia Cartographic Services Laboratory. Punch-registered overlays for each of the different press colors (black, cyan, yellow, and magenta) were compiled at 1:500,000 scale and photographically reduced to peel coat negatives at the printing scale of 1:1,500,000. The map was printed by offset lithography at Southeastern Color Lithographers, Athens, Georgia.

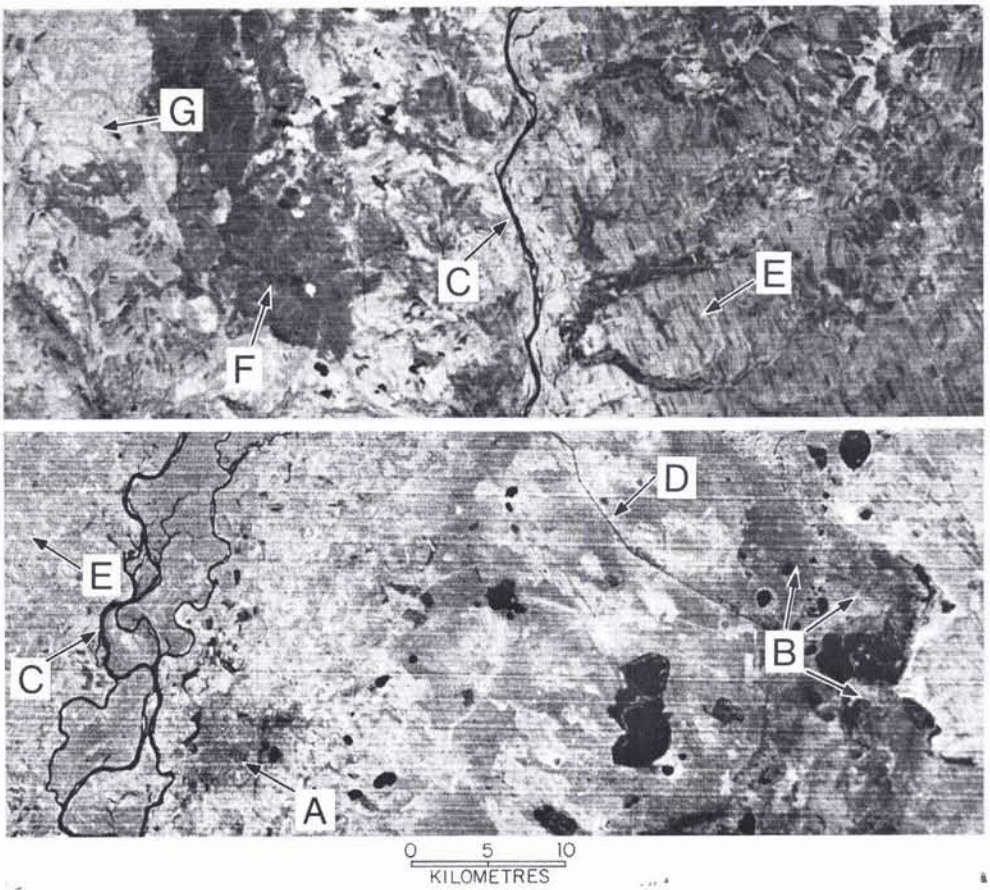

FIG. 3. Landsat image enlargements of some of the principal features and land use classes shown on the map insert. (A) Urban built-up land (Ch'i-ch'i-ha-erh); (B) Wetland; (C) Nun River; (D) Canal; (E) Extensive field cropland; (F) Clear Cut/Burned Land; (G) Forest.

CROPS OF THE NEW LANDS

Crop identification studies of the new lands are concentrated on two state farms with distinct field patterns (cover illustration and Figure 4). The largest of the two farm study areas occupies approximately 288 km^2 on the west bank of the Nun River (47°50'N Latitude, 123°50'E Longitude) about 50 km northwest of Ch'i-ch'i-ha-erh and was designated as Study Area I (see map insert). This farm area was reclaimed from marshland in recent years. The Landsat images reveal new roads and channels are currently being extended into the marsh to support further reclamation efforts. It is an ideal site for crop identification, with fields of regular configuration which average about 200 ha. Another farm area (Study Area II) of approximately 88 km^2 located about 20 km to the south of Study Area I was selected to test the possibilities for signature extension.

The major crops of the farm study areas are soybeans, spring wheat, corn, and millet. Intercropping practices (intertillage of two or more crops), favored in the small fields of the more densely populated regions of China, are less common in the Northeast where large fields, compatible with mechanized farming techniques, are preferred. Because of the larger fields and homogeneous crops, analysis of cropping patterns by means of Landsat image data is possible (Morain and Williams, 1975).

The principal aids to identification of crops include crop calendars, reflectance spectra, and images recorded on dates which maximize the reflectance differences between the crops (LARS, 1968; MacDonald, 1977). Crop calendar data for China are rather sketchy, but information contained in a report of the U.S. Department of Agriculture's Foreign Agriculture Service (1967), recent Chinese publications (Liao-ning tieh-ling College of Agriculture, 1976), and

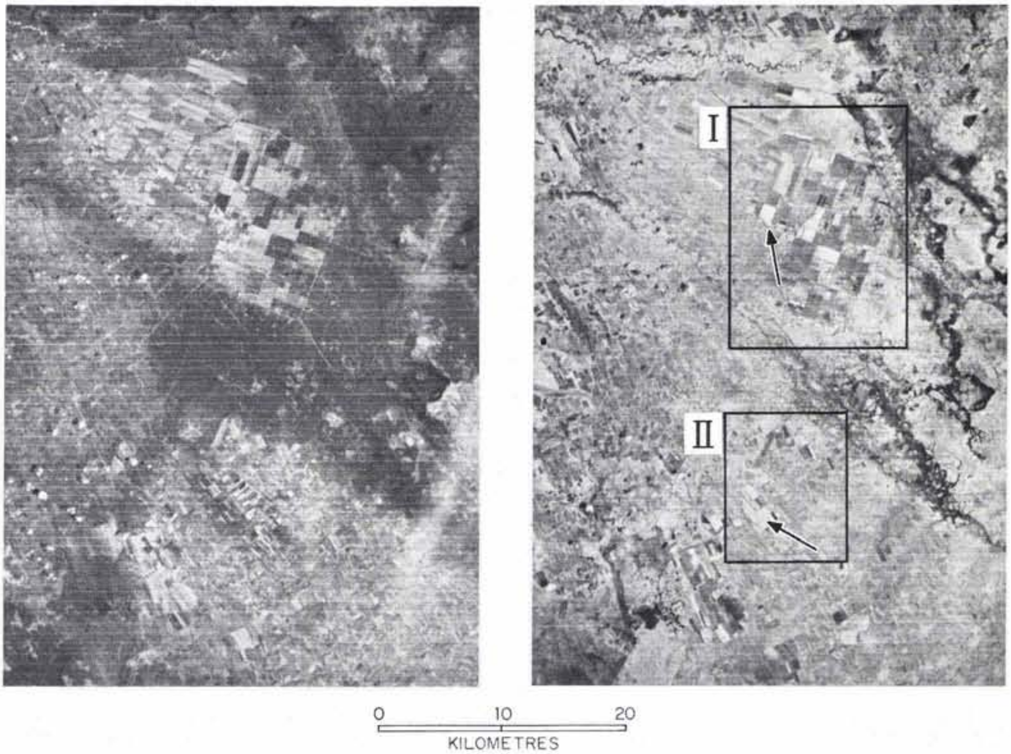

FIG. 4. Farm Study Areas I and II on band 5 (left) and band 7 (right) images recorded on August 1, 1975. Soybean field examples are indicated by the arrows.

analyses of the cropping practices in climatically analogous areas of North Dakota and Manitoba, Canada have permitted the construction of a calendar for the principal crops (Figure 5).

Figure 5 indicates that identification of specific crops is handicapped by the overlap in the growing seasons. In particular, soybeans, corn, and millet (of which there are early and late sown varieties) are grown throughout the summer months and are unlikely to be uniquely identified by simple correlation of the crop calendar with image data. A closer inspection of Figure 5, however, reveals that spring wheat and early sown millet are harvested by the end of July, by which time corn and soybeans are at a mature stage of growth with full canopies and maximum reflectance in the near infrared (Figure 6). Fields of late sown millet are still in the early stages of growth with the exposed underlying soil modifying the normal reflectance curves for green vegetation. These reflectance spectra, while subject to wide variations due to stage of plant growth, proportion of vegetation to soil exposure, moisture content, solar angle, etc., provide

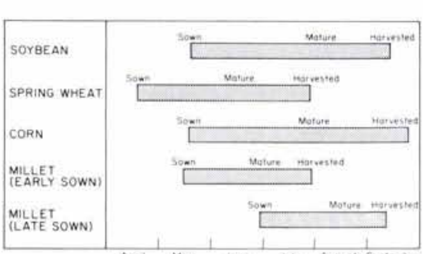

FIG. 5. Crop calendar for soybeans, spring wheat, corn, and millet.

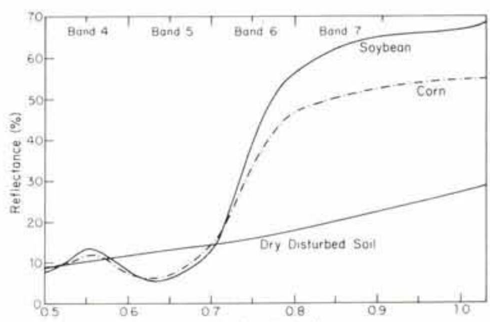

FIG. 6. Generalized spectral reflectance curves for soybeans, corn/millet, and dry disturbed soil.

an additional basis for discrimination of crops by both manual and computer assisted classification techniques (Allen and Richardson, 1968; De Boer *et al.*, 1974; Kanemasu, 1974).

Based on the crop calendars, Landsat image data were selected for three dates in the 1975 growing season: May 2, August 1, and October 1. Bands 5 and 7 images were subsequently obtained for each of these dates, and a computer compatible tape (CCT) for August 1. In the classifications described in the following paragraphs, the August 1 image data proved most useful for crop identification.

MANUAL CLASSIFICATION OF CROPS

Manual interpretations of 1:335,000 scale enlargements of the MSS bands 5 and 7 images were undertaken in conjunction with the crop calendars, crop reflectance data, and other background information in order to determine the feasibility of discriminating crops on the large fields of the state farms and, if possible, to establish training sets for use in computer assisted classifications.

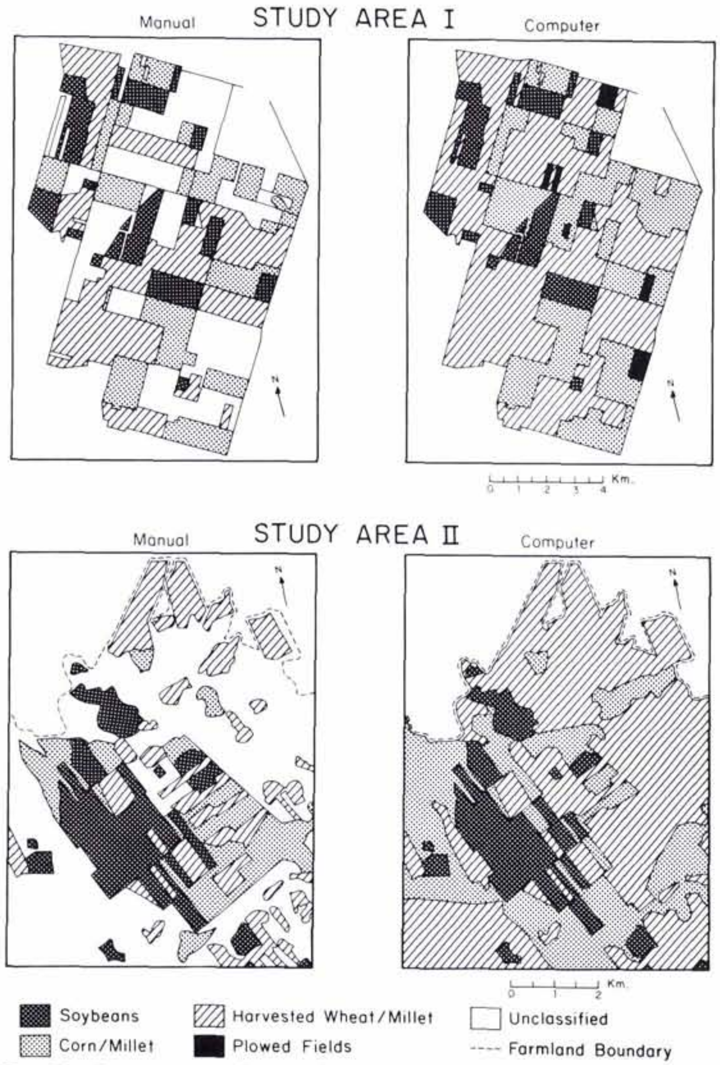

FIG. 7. Comparison of manual and unsupervised computer assisted classifications of field patterns in Study Areas I and II. Only those fields for which the crops could be identified with reasonable confidence were classified in the manual interpretation. The computer assisted approach provides a complete classification of the entire area.

Four distinct brightness (tone) classes could be ascertained on these images. In Study Areas I and II selected fields of more than 40 ha were assigned to the appropriate brightness classes and transferred to a base map of 1:50,000 scale with the aid of a Bausch and Lomb Zoom Transfer Scope.™ The brightness classification maps were then superpositioned on a light table, and the contrast for each field was associated with crop type. For example, a field classified as very bright on the band 7 map and very dark on the band 5 map was identified as soybeans. Soybeans are fully grown and produce the highest reflectance in band 7 at this time of year. Correspondingly, the contrast for soybeans between bands 5 and 7 is greater than for other crops. Corn and millet, with somewhat less contrast (between band 7 and band 5 images), could not be identified uniquely due to the overlapping growing seasons and were assigned to a single category: corn/millet. Fields with identical brightness classes on both bands 5 and 7 maps (no contrast) were identified as harvested wheat/millet since the reflectances of soil and dead vegetation are approximately equal in both the red and infrared portions of the spectrum.

This analysis procedure permitted the successful identification of crops in relatively large fields and was completed without undue difficulty. Crop type maps for the two study areas were then prepared, and the maps for Study Area I were used to establish training sets for the computer assisted classifications (Figure 7).

COMPUTER ASSISTED CLASSIFICATION OF CROPS

Computer programs for both unsupervised and supervised algorithms were employed to classify the crops of the two study areas. These programs were developed by the Office for Remote Sensing of Earth Resources (ORSER), The Pennsylvania State University, and modified for the University of Georgia IBM 370/158 computer system (McMurtry *et al.*, 1974; Borden *et al.*, 1977). A flow diagram (Figure 8) depicts the functional interrelationships of the routines employed. Initially, an unsupervised classification of the data for Study Area I was undertaken with the DCLUS routine, which forms clusters of pixels with similar signatures. After several iterations, a printout for ten clusters was produced which could be correlated with the field pattern distribution shown on the photographic enlargements in Figure 4. Examination of the tabulated mean response values in the four channels for each of the 10 clusters indicated that the difference in digital counts between bands 7 and 5 and between bands 5 and 4 could be used to reduce the number of clusters and to associate the clusters with particular crop types (Table 1).

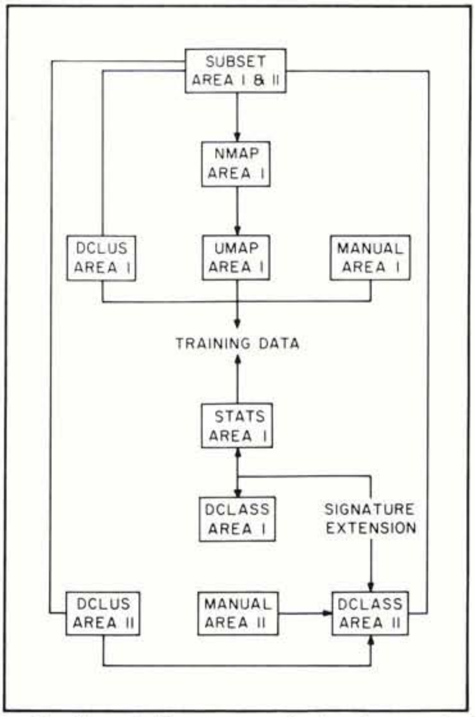

FIG. 8. Steps in the unsupervised and supervised approaches.

Wiegand *et al.* (1973), for example, demonstrated that a large reflectance difference between bands 7 and 5 (i.e., band 7 − band 5) indicates dense vegetation cover, whereas a minor difference is associated with bare soil or low vegetation density. Consequently, the difference (band 7 − band 5) may be considered a vegetation density index. Similarly, a large positive difference for band 5 − band 4 may be considered an index of bare soil or dead vegetation cover in an area, whereas a negative difference is associated with live vegetation or water.

Based on these principles, index values were computed for the 10 clusters in Table 1. Correlation of these index values with the crop reflectance curves, cluster distributions (on the line printer output), and the manually prepared map of Study Area I (Figure 7) indicated that the ten clusters could be reduced to four groups associated with particular crops or cover types: (1) soybeans, (2) corn/millet, (3) harvested wheat/millet, and (4) plowed fields.

After reducing the ten clusters to four

TABLE 1. VEGETATION DENSITY AND SOIL AND DEAD VEGETATION INDEXES DERIVED FROM THE UNSUPERVISED CLASSIFICATION

Cluster	Vegetation Density Index (Band 7 − Band 5)	Soil and Dead Vegetation Index (Band 5 − Band 4)	Group
1	39.0	−1.9	Corn/Millet
2	28.3	−0.9	Corn/Millet
3	26.4	0.9	Harvested Wheat/Millet
4	18.8	3.3	Harvested Wheat/Millet
5	15.6	3.0	Harvested Wheat/Millet
6	17.6	0.9	Harvested Wheat/Millet
7	11.8	3.4	Harvested Wheat/Millet
8	46.2	−2.7	Soybeans
9	58.9	−2.8	Soybeans
10	5.9	−0.5	Wetland/Plowed Fields

groups, training sets for the supervised classification of Study Area I were selected from the unsupervised classification line printer maps and the manually prepared maps. Spectral reflectance curves derived from the training data statistics (STATS) for the different crop classes for Study Area I indicated good separability of crop types (Figure 9). These training data were then employed with the computer classification routine (DCLASS) to produce a supervised classification of Study Area I. The computer line printer maps of the supervised and unsupervised classifications for Study Area I agreed to within one percent for the entire 61,000 pixel sample set indicating that the methods yield consistent results. As in other studies involving the use of CCT's, the principal advantages of the computer classifications were the ability to classify both large and small fields and to generate statistics rapidly, providing complete data for the entire study area.

In order to assess the possibilities of employing signature extension techniques for the analysis of regional Chinese agricultural patterns, the signatures for Study Area I

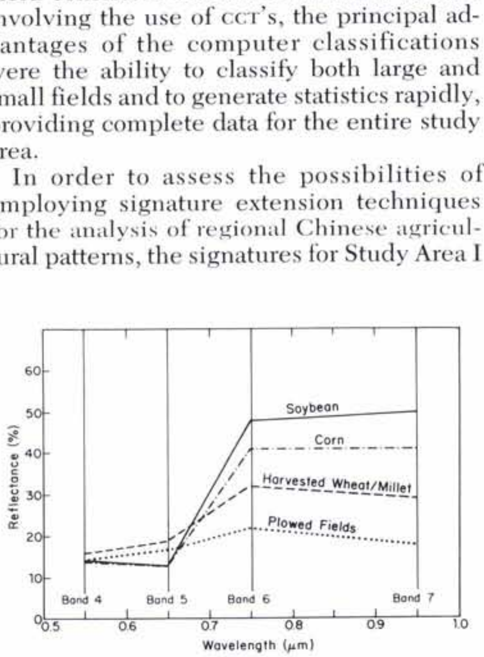

FIG. 9. Reflectance curves for the cropland classes derived from MSS data.

were applied to Study Area II using both the unsupervised and supervised classification algorithms (Hoffer and Goodrich, 1971). Comparative tabulations of the pixels classed as soybeans, corn/millet, and harvested wheat/millet on the two sets of line printer maps indicated an average discrepancy of about 13 percent between corresponding classes. A substantial portion of the discrepancies may be attributed to the fact that with the supervised routine approximately 10 percent of the pixels were placed in the unclassified category, indicating that the class boundaries based on the training statistics for Study Area I were too restrictive to be applied to Study Area II. Despite this problem, both the unsupervised and supervised maps were in good agreement with the manual classification maps and were judged to be acceptable for assessing the cropping practices on the state farms (Figure 7).

CROPS AND CROPPING PRACTICES ON STATE FARMS OF THE NUN RIVER BASIN

From Table 2 it is evident that the percentage of land allocated to various crops is essentially the same in both Study Areas I and II; that is, approximately 15 percent to soybeans, 20 percent to corn/millet, and 65 percent to wheat/millet. The area in soybeans is less than anticipated, and it is probable that the food requirements of an expanding population and the post-World War II shift of foreign markets has resulted in the conversion of land from cash crop (soybeans) to food crop (wheat and corn) production. Wheat is reported to have replaced millet as a principal food crop, and it is probable that spring wheat is the dominant crop on these farms. Corn is often alternated with soybeans and accounts for up to 25 percent of the farmland, which indicates that it has become a major crop in Northeast China. These percentages, while related directly to the

TABLE 2. COMPARISON OF CROPLAND STATISTICS FOR STUDY AREAS I AND II

	STUDY AREA I		STUDY AREA II	
	Hectares	Percent	Hectares	Percent
Soybean	2,880	14	800	13
Corn/Millet	4,860	23	1,290	20
Harvested Wheat/Millet	12,970	62	4,110	65
Plowed Field	160	1	110	2
Total Cropland	20,870	100%	6,310	100%
Non-Cropland	7,810		2,220	
Unclassified	80		260	
	28,760		8,790	

two farms studied in detail, appear to be valid for other large state farms in Northeast China and are supported by statements in the literature (CIA, 1971; Economic Guide Publisher, 1976; Liao-ning tieh-ling College of Agriculture, 1976).

CONCLUSION

Manual interpretation of Landsat image data of Northeast China has been used to prepare a land use map at 1:1,500,000 scale of the Nun River Basin, an area of approximately 184,500 km². This map portrays the spatial distribution of approximately 15,300 km² of new agricultural lands and substantiates published reports of extensive agricultural development in this region of China. These new lands have been reclaimed from areas of wetland and rangeland previously considered unsuited for agriculture and are easily recognized on Landsat images as patterns of large rectangular fields ranging in size from 20 to 800 ha. In contrast with the small fields and intensive human labor practices of central and south China, mechanized equipment is widely employed here.

Areal measurements on the map and Landsat images indicate that perhaps as much as 37,000 km² of wetland and rangeland within the Nun River Basin yet can be converted to agricultural lands. These figures suggest considerable potential for further agricultural development and land occupance in remote regions of China, but should not be interpreted as a solution to China's long term population and food production dilemma. In the context of China's huge and rapidly growing population, the contribution of these new lands will be modest.

Classification of crops on two large new land farm areas proved feasible through the use of comparative manual and computer assisted classification procedures conducted with the aid of crop calendars, reflectance spectra, and image data in photographic and CCT formats. Three crop categories could be identified on Landsat band 5 and 7 enlargements recorded on August 1, 1975: (1) soybeans, (2) corn/millet, and (3) harvested wheat/millet. At this time of year soybeans, corn, and late sown millet are mature and exhibit high to moderate reflectance levels in the band 7 wavelength interval of 0.8-1.1 μm, whereas wheat and early sown millet have been harvested, resulting in relatively low reflectance in both bands 5 and 7. These reflectance characteristics produce distinctive gray levels on the images and may be used to classify large, geometrically arranged fields by manual interpretation procedures.

Classification of the crops in small geometric and irregular field patterns is facilitated by computer assisted analyses involving either unsupervised or supervised algorithms. For a relatively homogeneous agricultural area such as the state farms, the differences in the mean digital counts (of band 5 − band 4 and band 7 − band 5) of the clusters produced in the unsupervised approach may be used to develop index values which can be related to crop type or to establish training sets for supervised classifications. These techniques proved effective for the remote study areas and resulted in classification products that indicate the cropping practices in Northeast China. It appears, for example, that emphasis is being placed on food crops such as wheat and corn which have replaced soybeans, millet, and kaoliang as the principal crops in the Northeast. This may be attributed to the shift of export markets and the requirement to feed a rapidly expanding population.

In the absence of definitive ground truth, the problems of obtaining spatial information about remote foreign areas such as Northeast China are severe. However, in many instances these problems can be overcome through the correlation of Landsat image data with available reports, maps, and other supplementary information in order to provide information of sufficient accuracy for analyses of land use and land development policies. A combination of manual and computer assisted classification is recommended in order to minimize cost and to maximize the accuracy and clarity of detail representation. Manual interpretation of Landsat images permits the rapid construction of regional map products, whereas the classification of CCT data of smaller sample areas results in a quantitative identification of land cover and the generation of summary statistics.

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