PRODUCTION OF ENHANCED LANDSAT IMAGERY FOR FOREST FIRE FUEL TYPE MAPPING OF NORTHEASTERN CHINA

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by

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ABSTRACT

This paper describes the production of forest fire fuel maps for the Jiagedaqi forest region in northeastern China. The information contained in these fuel maps will provide decision-making aids for fire control personnel. The fuel type maps, in the form of photographic images, were generated from the principal component enhancements of Landsat multispectral scanner data. For 12 winter scenes, standard operational procedures were developed to generate principal components, and for the subsequent special mapping of these components into visual color space. Color consistency was obtained across all Landsat frames. The enhancements were then recorded on 70 mm transparencies, photographically enlarged to color prints, and mosaiced for the complete region.

INTRODUCTION

In Canada, enhancement of Landsat multispectral scanner data has proven to be a valuable tool for forest fire management agencies. Photographic images of these enhancements provide forest fuel information which is useful for initial attack planning, presuppression planning, and fire growth modelling of actual forest fires. These photographic images also provide information on road networks, watershed systems, wetlands, and lakes. Standard forest inventory maps do not adequately provide this type of information. Rarely are such maps current enough to show recent new disturbances such as burns, clear-cuts, or insect-killed areas which are so important to fire behaviour. Also, inventory maps are too complex for fire control use. The maps have to be colored into stands of similar fire behaviour characteristics. This process is very time consuming and costly. Besides providing the current forest cover type information for operational fire situations, Landsat enhancements have proven to be very economical over large areas (Kourtz and Scott 1978). The objective of this study was to use Canadian equipment and procedures to generate similar fuel type maps for the Jiagedaqi forest region.

The Jiagedaqi forest region represents a significant portion of the available commercial forest reserves for northeastern China. Approximately 70 fires occur annually in this region and burn a considerable area. In the past, fires have exceeded 650 hectares in the northern part of the region and have been larger than 3600 hectares in the southern portion. The percentage of forest lost to fire is substantial when compared to North American standards. Approximately 3% of the region's forest cover is burned annually, as compared to the North American level of 0.1% or less (Goodman and Kourtz 1982). Modern forest fire management techniques are required to reduce the area lost to fire and to protect existing forest and new plantations.

A project is underway to develop and implement an appropriate, modern, forest fire management system in the Jiagedaqi region. The project is a cooperative effort between the Chinese Ministry of Forestry, the Canadian International Development Agency (CIDA), and the Ontario Ministry of Natural Resources (OMNR). The production of Landsat enhancements and the subsequent generation of photographic prints is a component of this project and was performed by the Petawawa National Forestry Institute (PNFI).

The fire management system being developed at Jiagedaqi will not use a large computer. For the fuel mapping project, this eliminated the possibility of creating a digital fuel database. An analog approach was required which would display the fuel information easily and conveniently. The Canadian experience is that fire control personnel prefer the photographic representation of enhancements over classifications. Enhancements indicate the broad forest cover types and transition fuel areas between major fuel type components, give more revegetation information in new cuts and burns, resemble aerial photographs and, most important, require human interpretation (Kourtz and Todd 1978). Photographic images of enhancements can be easily displayed at the fire center and will provide up-to-date knowledge and information on the forest cover types in the Jiagedaqi region.

The enhancement of Landsat imagery is, in some aspects, an art form. Many different enhancements can be created; each enhancement presents the information in a slightly different representation. Each enhancement utilizes different color tones and illustrates different information patterns. The choice of the optimal enhancement is based on a trial and error approach, especially when a new area is being processed. The optimal enhancement will make the best use of the color space, will present the required information in a clear display, and will be pleasing to look at. Color consistency in the enhancements of all frames being processed is another consideration. The choice of colors and color patterns in the enhancement may vary from user to user.

DESCRIPTION OF AREA AND DATA ACQUISITION

The Jiagedaqi Fire Management area is located in the extreme northeastern portion of China, in the province of Heilongjiang. The study area spans from 50° to 53.5° north latitude and from 121.5° to 127° east longitude. The eastern and northern boundary of the region is the Heilong (Amur) River which forms the international border between China and the Soviet Union. The size of the Jiagedaqi fire region is approximately 6.7 million hectares and requires 12 Landsat frames for complete coverage. Figure 1 shows the landsat coverage of the 12 scenes relative to the Jiagedaqi region; this map indicates the approximate location of the scenes and does not include scene overlap.

The terrain in the study region is typical of the Da Xinggan Ling (Greater Khinggan Range). The northern portion of the region has elevations ranging from 450 meters to 1100 meters, with peaks reaching 1400 meters. The southern portion has a more rolling terrain, with elevations reaching 800 meters. The valley bottoms are predominantly grass/muskeg, with forest cover on the uplands.

The forest cover varies significantly from north to south. The northern portion of the region is almost entirely forested and is approximately 70% coniferous. The major tree species in the area is *Larix dahurica*, with minor softwood components of *Pinus sylvestris*, *Pinus pumila*, *Picea obovata* and *Picea microsperma*. The treeline is about 1100 meters. The valleys support grass meadows and swamps of *Populus*, *Betula*, and *Salix* species. The south is characterized by hardwood forests; open, burned, and grass meadows are predominant.

Forest fuel type maps can be generated from either summer or winter Landsat imagery. Summer imagery is preferred because of the good separation of coniferous and deciduous stands, higher definition of water and road information, and the revegetation information available in the open and low vegetation areas. Winter imagery provides good coniferous and deciduous separation, with some age class and density information within the softwood areas. However, the snow cover does not provide good information of the open fuel classes. One consideration, in regard to the study area and winter imagery, was the large percentages of larch forests. From Canadian experience, winter imagery had caused confusion between hardwood and larch areas. Initially, summer/winter overlays were considered as a way to eliminate this confusion. However for the study area, the larch stands were clearly illustrated on winter imagery and overlays were not required. Other considerations which led to the selection of winter imagery was the availability of complete coverage, recent imagery within the last two years, and relatively cloud-free imagery. Since there were only two summer scenes which were cloud-free (less than 10%) and of good quality, winter imagery was used for this study. Twelve Landsat scenes were ordered from the Japanese Remote Sensing Center. These scenes range from January 23, 1985 to March 5, 1985 (Table 1). The dates provided complete snow cover. Scenes were generally all of good quality and were 100% cloud free.

PROCEDURES

The imagery was processed on the Image Analysis System at the Petawawa National Forestry Institute (PNFI). The system is based on a Vax 750 computer, which has a 1600 BPI tape drive, one 256 MB disk, two 200 MB disks, a Floating Point Systems 5300 array processor, and a DICOMED image recorder. The system uses DIPIX V-stream software.

The enhancement procedure is based on the Taylor principal component color display algorithm (Taylor 1974). Eigenvectors and eigenvalues are determined from the spectral signature statistics of selected training areas and are used to generate principal components. The Taylor algorithm maps (unpacks) these components onto three visual color dimensions of brightness, red/greenness, and blue/yellowness. Rotation of the eigenvector space can be performed to control the final color display components in order to emphasize particular areas of interest. The resulting color images show discriminations better than the original raw data bands.

Because the tree species in the study area were somewhat different from those in Canada, enhancement tests were conducted on several small test sites. The sites chosen were representative of the forest cover in the whole Jiagedaqi region. Principal components were generated using training areas of similar forest characteristics to those which had generated good results in the Canadian forest environment. As well, other possible components were generated and tested. In all cases Taylor transformations were employed to examine the possible color patterns which could be produced. A standard operational procedure was eventually developed to generate the same color enhancements across all 12 Landsat frames.

The sequence of events in the standard enhancement procedure is as follows:

- define the sample site areas to be used for training area definition;
- identify two training areas of desired fuel types;
- create spectral signature files for each training area; these files contain the means and covariance matrix statistics;
- create principal components;
- view principal components individually;
- perform a reverse polarization if necessary;
- unpack to red, green, and blue files for display purposes;
- create 70 mm slides using a DICOMED image recorder;
- produce a computer compatible tape (CCT) of the enhanced image.

THE ENHANCEMENT STAGES

The Initial Test Enhancement

For the initial test enhancement, a sample site was chosen representative of the whole Jiagedaqi region. The criteria for choosing the site included the presence of several stands of the dominant forest cover types (*Larix dahurica*, *Pinus sylvestris*, *Betula* and *Populus*), the presence of representative terrain and river patterns of the region, and availability of good recent ground truth in the form of inventory maps. Similar rules were later used to define the sample sites on other individual frames. On this site, several different enhancements using several different training areas were created and tested. The enhancement which made the best use of the color space and which gave good detail and contrast in different fuel type areas was selected.

Defining the Training Areas

For the enhancement process, sample sites and training areas had to be identified on other frames. From Canadian experience, similar enhancements had been obtained by applying the eigenvectors to neighboring scenes with similar dates. A neighboring scene is within one row and/or orbit number and within one or two days of the original sample site frame. Figure 1 indicates the proximity of frames while Table 1 indicates the frames with similar dates. Table 1 shows that the 12 frames were grouped into five scene categories. One sample site was then identified in each scene group. For groups with more than two scenes, the sample site scene was the scene with the middle date. This approach speeds up the enhancement process over a large area by avoiding the time consuming process of creating many sample sites and training areas. Also color consistency is maintained over all of the enhancements. The same criteria which had been used for defining the sample site in the trial test area were followed on other frames.

Two types of training areas were used for producing principal components in the final enhancement. These training areas consisted of a general area and a softwood/mixedwood area. The composition of these areas is as follows:

general area:
- 30% larch/mixedwood
- 30% Scots pine/hilltop cover types
- 30% hardwood/open/low vegetation
- 10% hardwood

softwood/mixedwood area:
- 70% softwood/mixedwood/Scots pine
- 15% larch
- 15% hardwood

To derive these compositions, several distinct forest cover types were defined. These types could be identified from the available inventory maps and from previous knowledge of cover type patterns and textures on landsat imagery. The cover type definitions included stands of larch, Scots pine, hardwood, and mixedwood as well as open and hilltop areas. These defined areas were then combined to derive the composition of the two training areas. The percentages of the training areas were used as a general guideline. Generally, the size of the training areas averaged about 30,000 pixels for the general area and 10,000 pixels for the softwood/mixedwood area.

Deriving Principal Components

Signature files were created for each of the two training areas. These files contained the means, standard deviations, and covariance matrices. For the creation of these signature files only bands 4, 5, and 7 were used. From the initial test runs, it was determined that the first components were being dominated by the infrared bands. To reduce this effect, band 6 was not used. The signature files were then passed through a Karhumen-Loeve transformation to generate the principal components. The first two principal components from the general training area (labelled GE01 and GE02) were combined with the first component of the mixedwood training area (labelled SF01). When these components were examined individually, GE01 provided an overall clear, bright picture of the sample area, GE02 showed the Scots pine and hilltop stand areas in dark contrast with little detail in the remainder of the area, while the SF01 component provided greater detail in the coniferous stands than appeared in the GE01 component. This pattern existed for three of the five sample sites. For the other two sample sites, the second component of the general training area had different color contrasts; the Scots pine areas were light instead of dark. For these two sample sites we applied a reverse polarization in the principal component generation stage to make the component similar to the others.

The final enhancement stage was the unpacking of the principal components. The principal components are basically informationally independent components which are then mapped into the dimensions of brightness, red/greenness, and blue/yellowness. They are unpacked into red, green, and blue components for display on color terminals. The final enhancement made good use of the color space for winter imagery. The dark bluish green areas were softwood, which in this area is predominantly larch, the light green areas were mixedwood fuel types, the yellow was hardwood fuel types, the reddish colors were Scots pine/hilltop fuel types, and the open/low vegetation areas were white due to snow cover.

Applying the Principal Components

The principal components were then applied to scenes of similar dates and within the same proximity to the sample site scene. As mentioned earlier, this application of principal components eliminates the need for sample site and training area definitions on each frame, maintains the integrity of the enhancement over a large area, and saves considerable time.

Table 1 gives the details of how the enhancements were generated for the entire Jiagedaqi region. As can be seen in the table, seven scenes used a standard enhancement procedure and five scenes required a reverse enhancement, in that the second component required reverse polarization. The sample site scenes are identified in the left hand column. Scenes which are grouped together indicate frames which had enhancements transferred from the sample site scene. These frames were scenes of similar dates, usually within one day of the chosen sample area date and were the adjacent scene frame (refer to Figure 1 for relative scene proximity). One of the exceptions to this rule was the X01 scene, which was three days from the sample site date and four orbits removed. The other exception was the W01 and U01 scene pair. The enhancement colors in these two scenes were the same but the quality and texture were inferior. This was probably due to the poorer quality of this data set; the raw data was darker than the other frames. Therefore, separate training areas had to be used for these two scenes. For W01 the standard enhancement applied, and for U01 the reversed enhancement applied.

Creating the Final Products

The enhancements were then processed on the Dicomed image recorder. The Dicomed records data files on 70 mm positive film transparencies. For each scene, images were recorded for the entire frame and for ¼-scene segments. These transparencies were then processed onto 10" x 10" and 20" x 20" photographic prints. These prints represent the actual fuel type images which are to be used by the fire control personnel. The 10" by 10" prints of the entire scenes were mosaiced for the whole regional picture. Also for each scene, computer compatible tapes of the enhanced unpacked files were made for later display.

Production Time

The approximate time required to perform enhancement procedures on the PNFI image analysis system is shown below. For a full Landsat scene an enhancement can be generated within a normal three hour session on the system.

The times for the various enhancement stages are listed below:

- inputting tape	20 minutes
- identifying a sample area	15 minutes
- creating training areas	20 minutes
- creating signature files	10 minutes
- creating principal components for two training areas (using array processor)	30 minutes
- checking individual principal components	15 minutes
- unpacking components	50 minutes
- creating CCT of the enhancement	20 minutes
	180 minutes

CONCLUSIONS

The enhancements proved to be a quick, appropriate and inexpensive means of providing forest fire fuel maps for the Jiagedaqi region. The photographic prints of these enhancements will provide fuel information which can be used for operational planning during actual forest fires.

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TABLE 1 - Enhancement Scenes

Standard enhancements:

TRAINING AREA	SCENE NAME	DATE	PCN NO
1	K01	FEB. 4, 1985	119-24
2	M01	FEB. 27, 1985	120-24
	S01	FEB. 27, 1985	120-25
	N01	FEB. 26, 1985	121-24
	T01	FEB. 28, 1985	119-25
3	W01	JAN. 26, 1985	120-23
	X01	JAN. 23, 1985	123-24

Reversed enhancements:

TRAINING AREA	SCENE NAME	DATE	PCN NO
4	O01	MARCH 5, 1985	122-23
	P01	MARCH 5, 1985	122-24
	R01	MARCH 4, 1985	123-23
	Q01	MARCH 6, 1985	121-25
5	U01	JAN. 25, 1985	121-23

Figure 1 - Landsat coverage of JIAGEDAQI Region