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**Interpretation guide of natural geographic features from ETM+
Landsat imagery and aerial photography: Wooded areas**

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Introduction

The purpose of this project is to create a visual interpretative guide to the natural geographical entities in the geospatial database (GDB) using Landsat7 ETM+ imagery and aerial photography. The methodology and information fact sheet were developed by Provencher and Dubois (2004a), and the application of this procedure to a test case has already garnered a consensus among the staff of CTI at Sherbrooke (Provencher and Dubois (2004b)). The meanings of the sections of the fact sheets are explained in the appendix.

The eight natural entities in the GDB (Centre for Topographic Information, 2004) fall under eight themes that are grouped into three domains: hydrography, landforms, and vegetation (**Table 1**). In practice, for interpretive purposes they are often subdivided further and represented by 17 fact sheets.

N.B.: Elaboration of the illustrative examples and potential elements of confusion was constrained by the limited time allocated to this guide. It is recommended that they be supplemented as other cases are documented, especially from Landsat ETM+ imagery.

Table 1: Hierarchy of natural geographical entities

Domain	Theme	Sub-theme	GDB entity	Fact sheet	
Hydrography	Watercourse	Perennial watercourse	Permanent water	Permanent water	
		Alluvium	Intermittent water	Intermittent water	
		Waterfall	Water disturbance	Waterfalls and rapids	
			Rapids	Water disturbance	Waterfalls and rapids
	Waterbody	Perennial freshwater body		Permanent water	Permanent water
			Alluvium, rocky surface	Intermittent water	Intermittent water
			Saltwater	Permanent water	Permanent water
		Alluvium, rocky surface (tidal flat)		Intermittent water	Intermittent water
			Reef	Water disturbance	Reef
			Wetland	Tundra pond	Saturated soil
	Palsa bog	Saturated soil		Palsa bog	
	Marsh, swamp, and uniform peat bog (wetland)	Saturated soil		Wetlands (marshes and swamps, peat bogs)	
		String bog	Saturated soil	Wetlands (string bog)	
Landforms	Glacial landform	Glacial debris	Landform	Glacial debris	
		Esker	Landform	Esker	
		Moraine	Landform	Moraine	
		Glacier, glacial ice cap, and ice shelf	Permanent snow and ice	Permanent snow and ice	
	Periglacial landform	Polygonal soil	Landform	Tundra polygon	
		Pingo	Landform	Pingo	
	Littoral landform	Barrier beach and spit	Landform (sand)	Barrier beach and spit	
	Eolian landform	Dunes	Landform (sand)	Dunes	
Vegetation	Wooded region		Wooded region	Wooded region	

1- Feature name

Wooded Areas

2- Hierarchy

Vegetation – wooded areas.

3- Definition

Areas with more than 35% (aerial photograph) or 50% (ETM+ images) coverage with shrubs and/or trees with a minimum height of 2 m. The percentage difference between aerial photography and ETM+ imagery comes from the fact that ETM+ resolution is inadequate.

Wooded areas within built-up areas (urban wooded areas or parks) and nurseries (agricultural zones) are not mapped. When aerial photographs are used, regions that have been reforested (plantations), burned, or devastated by epidemic (regenerating) are considered wooded. In the case of ETM+ imagery, these regions will not be considered, except for plantations.

4- Summary table of identification elements

Table 2: Summary of elements identifying wooded areas

Form	Areas of all shapes with coverage comprised of shrubs and/or trees with a minimum height of 2 m.	
Dimensions	All dimensions	
Topographic position	All positions Elevation and latitude limited	
Drainage	Variable but usually good	
Vegetation	Populated with hardwood, softwood, and mixed species	
Means of formation	Germination and growth depending on favorable soil and climatic conditions	
Status	Relatively stable depending on natural processes and human activity	
Spatiotemporal variations	From the event to millennial scale, depending on natural processes and human activity	
Environment	All land environments with good drainage and moisture, except glacial and periglacial environments	
Identification in the image	Combination of bands 4-3-2	
Identification in B/W aerial photo	Average to dark grey tones Granular texture Height shown in stereoscopy	
Elements of confusion	Areas of shrubs less than 2 m in height, unstocked regions	

5- Characteristics

5.1- Specific to feature

5.1.1- Form

Areas of all shapes with coverage comprised of shrubs and/or trees with a minimum height of 2 m.

5.1.2- Dimensions

Areas of all dimensions

5.1.3- Topographic position

All topographic positions up to a maximum elevation in mountain environments and decreasing depending on latitude. For example, the summit of Mont Albert, in Gaspésie, has no tree cover from about 1000 m to 1100 m of elevation (48th parallel), whereas the tree line on peaks in the Rockies (49th parallel) ranges from 1900 m to 2100 m in southern British Columbia, from 1300 m to 1500 m in southern Yukon (60th parallel), and from 400 m to 500 m in northern Yukon (67th parallel).

5.1.4- Drainage

Drainage is very variable, ranging from excellent to poor, but is usually good.

5.1.5- Vegetation

Tree or shrub growth of hardwood, softwood, or mixed species

5.2- Related to feature dynamics

5.2.1- Means of formation

Germination and growth of trees or bushes as the result of the emergence of land, loss of permanent snow and ice cover, climate warming allowing extension beyond the tree line, and any other natural process or human activity.

5.2.2- Status

The main areas of tree or shrub vegetation are inherited, but can be very dynamic locally depending on natural processes and human activity:

- Climate enhancement or deterioration allowing or preventing trees or shrubs from growing at higher elevations or latitudes. These climatic variations may also enable permanent snow and ice to accrete to the detriment of wooded areas or, on the other hand, enable wooded areas to expand.
- Emersion or submersion of land allowing extension of vegetation (northern Canada) or, on the other hand, a loss of habitat (Atlantic Provinces).
- Erosion of marine, lagunal, and lacustrine shores as well as fluvial and estuarial banks resulting in the loss of habitat or, on the other hand, growth through land gained by sedimentation.

- Natural destruction of forest by fire or epidemic, and its subsequent regeneration (but still considered as wooded areas).
- Very localized loss of wooded areas caused by submersion as the result of beaver dams.
- Loss of wooded areas by human activity such as urbanization, expansion of agricultural land, infrastructure construction, and timber harvesting. ;
- Wooded areas expanded by human activity: plantations

5.2.3- Spatiotemporal variations

Variations in wooded areas occur at all time scales:

- Millennial to centennial (variations in the related sea level, climatic variations)
- Decadal (erosion or sedimentation, epidemics, regeneration)
- Annual or event-related (fire, human activity)
- Seasonal (appear especially in areas of hardwood or mixed species)

5.3- Related to the environment

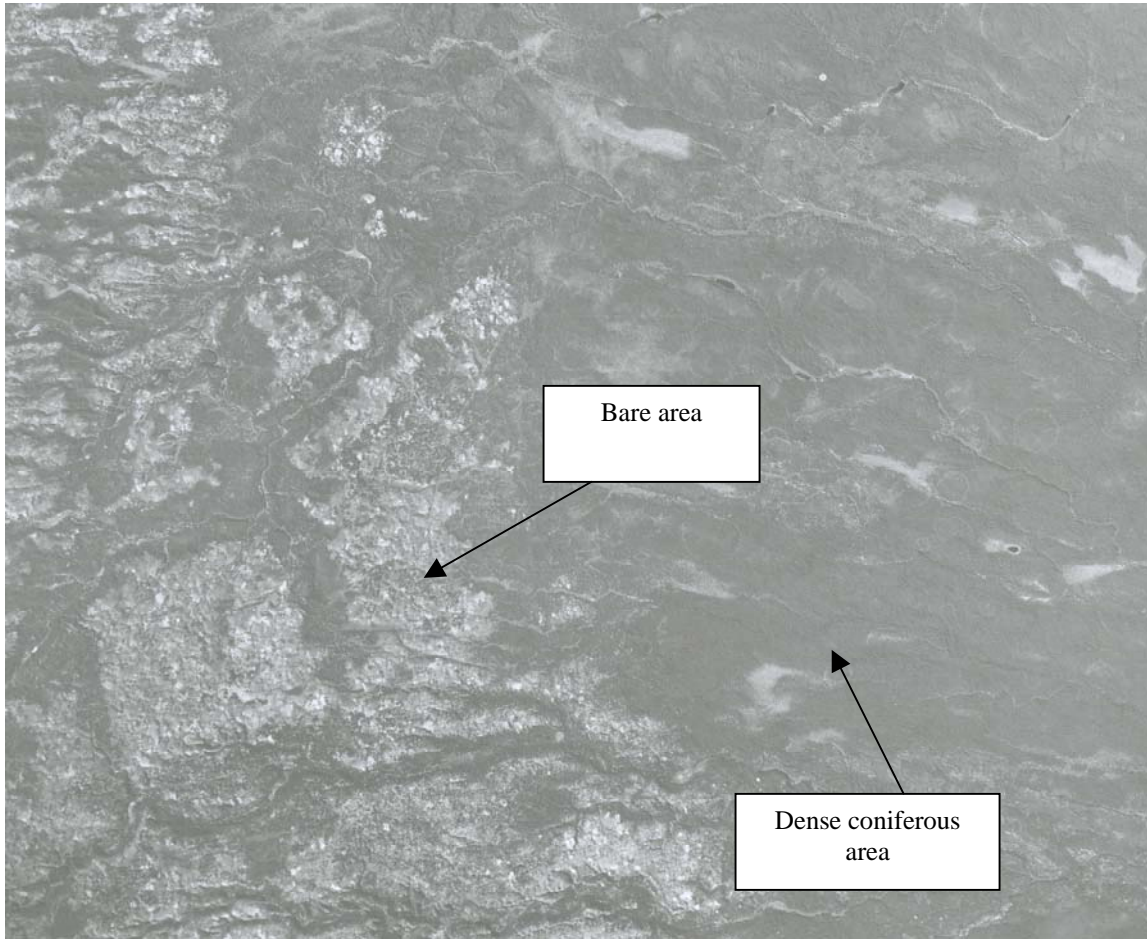
All land environments that are relatively well drained or receive adequate moisture, except for glacial and periglacial environments at high elevations or latitudes.

6- Optimal conditions for identification

In aerial photographs, wooded areas are easily identified, especially with stereoscopy.

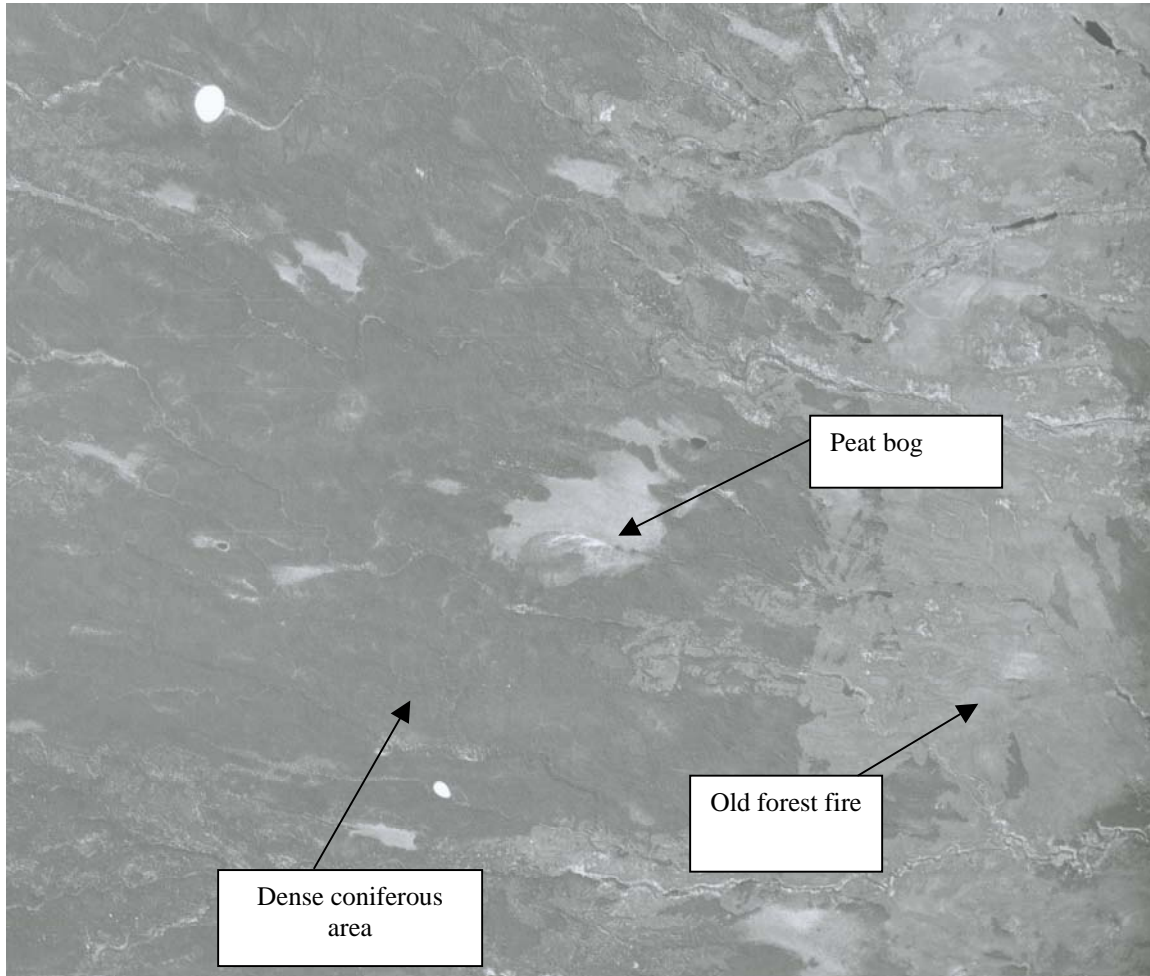
Imagery must be taken during foliation. The spectral reflectance of wooded areas changes throughout the growing season; this is particularly true of hardwood and mixed forests. This complicates the use of imagery to visually identify vegetation. Consequently, the most commonly used combination of bands is 4-3-2 because: 1) band 4 has strong reflectance due to its reaction to chlorophyll; 2) band 3 has low reflectance and is not very sensitive to the green of vegetation; and 3) band 2 leads to discrimination between the various different types of vegetation.

7- Examples



Source : photo A14525(13), T.S.C.A.P. 54, Original scale 1 : 60 000, Map 42 I/4, 50° 00' N – 85° 44' O, Coral, area Ontario

Figure 1: Example of wooded areas and unwooded areas in northern environments, which can be spotted both in aerial photographs and ETM+ imagery.



Source : photo A14525(13), T.S.C.A.P. 54, Original scale 1 : 60 000, Map 42 I/4, 50° 00' N – 85° 44' O, Coral Map , Ontario

Figure 2: Example of wooded areas and unwooded areas in northern environments (peat bog) that can be mapped from ETM+ images and aerial photographs. The site of an old fire can be easily spotted both in aerial photographs and ETM+ images (band 6).

8- Interpretation

8.1- Critical path

The critical path comprises two phases: discrimination and delimitation of the form as well as its identification.

8.1.1- Discrimination and delimitation

Wooded areas are easy to identify in aerial photographs due to their medium to dark grey tone, coupled with a granular texture. Near the boundary with areas of shrubs less than 2 m in height at high altitude or latitude and in regeneration zones after harvesting, it is necessary to 1) assess the percentage of shrubs and/or trees with a minimum height of 2 m (35%) depending on the area; 2) the minimum height of trees and shrubs (at least 2 m) depending on

the shortest shrubs. Stereoscopy is therefore necessary to distinguish between them; the interpreter's experience is of critical importance. In the case of areas with hardwoods, the percentage assessment can vary depending on the state of foliation in the year when the photographs were taken.

As mentioned in Section 6, the combination of bands 4-3-2 yields the best discrimination of vegetation cover. Delimitation based on vegetation height is, however, to achieve, since spectral response is not affected.

8.1.2- Identification

The process for identifying wooded areas requires the analyst to deal with different elements of confusion and discrimination (Table 2). Discrimination accuracy is directly proportional to the analyst's level of knowledge and experience.

8.2- Verification with complementary sources of information

Although there are forestry maps in all provinces and territories, they are not always current.

9- Elements of confusion

Table 3: Elements of confusion and discrimination between wooded areas and other features or forms

Feature or Form	Elements of Confusion	Elements of Discrimination	Examples
Zones of shrubs less than 2 m in height	- Height of trees and shrubs (less than 2 m)	- Stereoscopy - None with ETM+	
Regions with low density of trees	- Estimated percentage of trees (35% with photos and 50% with images) - State of the foliage	- Interpreter's experience - Photograph or image taken during foliation	

10- Bibliography

None

Appendix: the meanings of the sections

1. Name of entity

The name of the entity as it appears in the GDB and in Topolan7.

2. Position in hierarchy

The position of the entity in the hierarchical structure of entities in the GDB.

3. Definition

A brief description based on the entity's principal characteristics and allowing it to be distinguished from any other natural or manmade entity in the GDB.

Only the core features are part of the definition. A detailed description of the characteristics necessary for identification is given in Section 4.

4. Summary table of elements of identification

Presentation of a table summarizing the entity's characteristics (Section 5), of the optimal conditions for identification on ETM+ imagery and black and white (B/W) aerial photography (Section 6), and of the elements of confusion (Section 9).

5. Characteristics

Categorization and description of the characteristics useful for visual identification of the entity.

5.1. Specific to the entity

Characteristics unique to the entity that allow all aspects useful for its identification to be grasped.

5.1.1. Shape

Distinction between linear, point, and areal shapes, three-dimensional pattern of the entity.

5.1.2. Dimensions

Expanse (length, width, diameter) and height of the entity: minima, maxima, and means.

5.1.3. Topographic position

Location of the entity relative to major landforms: drainage basin, mountain, plateau, plain, valley, slope, etc.

5.1.4. Drainage

Surface moisture, outside of saturated zones, in connection with the texture of the materials in the entity.

5.1.5. Vegetation

Presence of vegetation typical of the entity or patterns of plant associations making it possible to distinguish the entity.

5.2. Relative to the entity's dynamics

Characteristics pertaining to the origin and the state of the entity.

5.2.1. Emplacement process

The agent or set of agents responsible for the entity's emplacement and evolution.

5.2.2. State

Dynamic state of the entity: inherited or current. In the case of inherited features, we speak of paleolandforms; in the case of current landforms, we speak of their ongoing formation.

5.2.3. Spatio-temporal variations

Variations in the entity or its appearance that are functions of cyclical conditions (seasonal, multi-year, etc.) or event driven.

5.3. Relative to the environment

Characteristic of the conditions in the entity's milieu and its relationship with other entities or forms present in this milieu.

6. Optimal conditions for identification

Drawing on documentary sources and the experience of the participants, establishment of the optimal conditions for visual identification of the entity. Using satellite imagery, determine the capability of Landsat7 ETM+ to capture the characteristics of the entity and identify the band or combination of bands best for visually distinguishing and identifying the entity. Using B/W aerial photography, identify the hues and textures that are most representative of the entity. In cases in which the relief may be significant, recommend the use of stereoscopy.

7. Examples

Illustrating the entity with examples reflecting several of its aspects:

7.3. Land-based photography

Photographs of the landscape that present one or several examples of the entity's aspects, as they might be seen from the ground.

7.3. Aerial photography

Oblique or vertical aerial photographs that present one or several examples of the entity's aspects, as they might be seen from the air.

7.3. Satellite imagery

Satellite images (from Landsat7 ETM+) that present one or several examples of the entity's aspects, as they might be seen from space.

8. Interpretation

Identification of the entity proceeds from interpreting the information in the imagery or aerial photography and complementary sources of information. The quality of the outcome of this interpretive activity will depend upon the knowledge and the experience of the analyst.

8.1. Critical path

Establishing a unique critical path of interpretation for each entity from the imagery or aerial photography on the basis of its characteristics.

8.1.1. Distinction and delimitation

The possibility of distinguishing and delimiting the shape on the image or aerial photograph has been established and the criteria for success have been described.

8.1.2. Identification

Contrasting the various elements of confusion and recognition with other entities or forms for purposes of identification.

8.2. Use of complementary sources of information

Complementing or cross-checking the interpretation with additional sources of information that are easily accessible, such as those on known Internet sites.

9. Elements of confusion

Identifying the entities and forms with which the entity in question can be confused in a table, along with the differentiating features.

10. Bibliography

A list of useful documents quoted in the previous sections.