

Chapter 2

Historical Aerial Photography for Landscape Analysis

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OBJECTIVES

Historical patterns and spatial heterogeneity can greatly influence dynamics of contemporary landscapes. Historical conditions lay the foundation for contemporary management options and can help guide restoration goals. While historical spatial data sources are not generally common, historical aerial photography provides the longest available, spatially contiguous record of landscape change. Aerial photography has been routinely collected since the 1930s in many parts of the world and has aided land management for over 75 years. Aerial photography often forms the basis of a variety of maps routinely used by managers, including forest ecosystem inventories and digital elevation models (or DEMs). Aerial photographs generally provide higher spatial resolution information than widely available (and free) satellite imagery (e.g., Landsat). Thus, aerial photographs have unique value for mapping historical landscape baselines and assessing long-term landscape change. For these reasons, understanding how information is derived from aerial photography is enormously important for landscape ecologists. The objectives of this lab are to help students:

1. Understand how landscape heterogeneity can be characterized using aerial photographs;
2. Gain introductory exposure to the benefits and challenges associated with interpretation of aerial photography; and
3. Explore the utility of historical spatial data for characterizing baseline conditions and understanding landscape change.

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This lab is divided into several parts designed for teams of students to analyze aerial photography and then compare and discuss their results. Part 1 provides a fun introduction to viewing aerial photography “in stereo”. Part 2 explores the comparative heterogeneity and fragmentation seen in historic and contemporary landscapes. Students manually photointerpret contemporary and historic images from the same landscape and then compare results with their classmates and to those from a professionally trained interpreter. Part 3 introduces additional considerations including potential sources of error in maps, how such uncertainties can impact their utility, and how terrain and productivity patterns can impact photo interpretation and landscape change. While our examples primarily focus on coastal temperate forests, it is important to note that aerial photographs are used to assess and monitor a diversity of landscapes all over the world, including aquatic, marine, tropical and polar environments. Several of the exercises can be adapted to use imagery from your local region and additional more advanced exercises are available on the book website.

At a minimum, students will need printed copies of the images in the **StereoPairs** and **OrthoPhotos** folders as well as the tables which are provided digitally (see book website), along with a few colored pens/pencils and a calculator. Your instructor may also wish to provide some plastic overlay transparencies on which to draw. A hair tie, for holding one’s hair back, may also be helpful. A computer is not necessary if ALL the images in the rest of the **Spatial Data** folder are printed; otherwise, students will need to view these additional images on-screen. Your instructor may wish to provide a stereoscope, which is useful but not required, for demonstrating 3-dimensional (3-D) concepts in the lab.

INTRODUCTION

Aerial photography is used extensively in environmental monitoring and management (Morgan et al. 2010). Captured over a variety of spatial scales, aerial photographs are used for a wide variety of purposes in resource management, from detailed surveys of individual trees to general land cover mapping over broad extents. Common uses include creation of forest inventories, disturbance mapping, estimating productivity, and wildlife management (Avery and Berlin 1992). The fine detail (high spatial resolution) of some aerial photography is particularly well suited for mapping small features or ecosystems (Fensham and Fairfax 2002; Tuominen and Pekkarinen 2005). For example, aerial photographs have been used to identify canopy gaps and forest structures important for wildlife (Fox et al. 2000). Additional examples are shown in Figure 2.1. Examine these four images and try to identify some recognizable features.

Archival historical aerial photography can also provide valuable information on prior or baseline landscape conditions, making the imagery useful for mapping and monitoring change over time (Morgan and Gergel 2013; Cohen et al. 1996; Fensham and Fairfax 2002). The first known aerial photograph was captured in 1858 from a balloon over France. However regular collection did not begin until World War I, primarily for military reconnaissance (Lillesand and Kiefer 2004). Because historical

aerial photography offers a window into the past, it has been invaluable for detecting encroachment of invasive species over time (Hudak and Wessman 1998; Laliberte et al. 2004; Mast et al. 1997).

Part 1. Viewing Stereo pairs

Aerial photographs are captured with an airborne camera and represent the reflectance (or relative brightness) of features on the ground. Aerial photographs are often acquired along a **flightline** (i.e., a path flown in a constant direction over a targeted area). A critical component of collection along flightlines is that adjacent



Figure 2.1 Examples of landscape features distinguishable from fine scale aerial photography. Shown is an area from Washington State, USA in 2006. More details can be found in Tomlinson et al. 2011 who contrasted this imagery with similar locations in 1949 to examine changes in fish habitat. (a) Sinuosity (curvature) of rivers and the extent of riparian zones (1:5000)



Figure 2.1 (continued) **(b)** Agricultural type (hay field vs. orchards) (1:5000). Orchards are indicated with their dark green, regularly spaced tree crowns. Hay fields are beige with a smooth texture. **(c)** Sediment loads and relative depth in aquatic environments (1:10,000)



Figure 2.1 (continued) (d) Urban-wildland interface and urban density (number of houses or roads in an area) (1:10,000)

photographs possess some degree of spatial overlap (often up to 60%). This overlap presents the landscape from two different viewpoints, and thus can be used to view various features in 3-dimensions. Any two adjacent photographs with overlap are referred to as **photo pairs** or **stereo pairs** and are most easily viewed in 3-D with the aid of a stereoscope.

EXERCISE 1: Seeing in Stereovision

Example stereo pairs have been provided in the folder labeled **StereoPairs**. If your instructor is able to provide a stereoscope, you can follow these steps. If no stereoscope is available, skip to the “*Low-Tech*” Method 2.

Method 1: Stereoscope

To view with a stereoscope, the simplest approach is:

1. Examine the two photographs and notice the zone of overlap (i.e., the portion of the landscape captured in both images).
2. Place the photographs within the field of view of the scope. Be sure to place the left and right images under the corresponding left and right eyepieces.
3. Within this overlapping zone, identify the same notable feature (or location) in each image with a finger.
4. Now looking through the scope, align your two fingers so they match up within your field of view. The notable features should then also be close to aligned and thus appear 3-D.

Viewing in stereo is not easy for everyone, particularly for people with unequal vision in each eye. For those who find it easy with a stereoscope, you may even be able to view photo pairs in stereo without one.

Method 2: Low-Tech

1. Using Figure 2.2, place an index card (or piece of folded paper ~20 cm high) on the line between the photographs.
2. Position your forehead directly on top of the card. The index card forces your left eye to focus on the left photograph and your right eye to focus on the right photograph.



Figure 2.2 Stereo pair from coastal British Columbia captured in 1937. A printable version is available from the book website in the **StereoPairs** folder (see **Site 1**)

3. Concentrating your vision (and “relaxing” your focus), imagine bringing the two images together so they align in the middle of your view. With some patience, hopefully the image will “pop” for you at some point, giving you a deep view of the terrain of the valley.
4. It may also be helpful to try and focus your eyes “through” or “past” the images and then pick a feature (such as the river), and attempt to bring it together into focus.
5. Remember, only the area of photo overlap will be visible in 3-D. You will also see the outer parts of the two images (but blurry and not in 3-D) on either side.
6. This may not work for everyone, so move on after trying for a few minutes.

Viewing stereo pairs in 3-D without a stereoscope requires practice and patience, but once your skills become more advanced you will find it much easier to achieve stereovision. You might also wish to try again at the end of the lab after your eyes rest.

Modern aerial photography is commonly captured in color which provides more information than **panchromatic** (black and white) historic photographs, particularly for species classification and assessment of vegetation health. Conventionally, most aerial photographs were captured with a film-based camera and then converted into digital format via scanning (Wolf and Dewitt 2000). However, a recent shift towards digital cameras has aided instantaneous capture of photographs in digital format with integration of geographic positional system (GPS) data. Unmanned aerial vehicles (UAVs) or “drones” are providing novel opportunities for capturing high resolution digital photography in ways that link extremely well with spatial ecological questions (Getzin et al. 2014) and connect well with other monitoring approaches such as satellite imagery, fieldwork, and citizen science (Turner 2014).

Next, you will examine aerial photographs over two time periods and explore how different methods of analysis can be used to extract a diversity of information useful in answering important landscape ecological questions.

Part 2. Exploring Manual Photointerpretation

As much an art as a science, manual interpretation has been the primary technique used to derive ecological information from aerial photographs for eight decades (Morgan et al. 2010). While techniques have evolved greatly, from the use of plastic overlays to complex computer software, the basic approach remains similar (Avery and Berlin 1992).

First, the process of **polygon delineation** creates a series of polygons on an image (perhaps drawn “freehand”) in order to delineate homogeneous areas (or patches) with similar properties. In this lab, we will be focusing on **forest patches** (or forest stands), areas which are relatively homogenous with respect to tree size and species mix. Forest polygons are routinely delineated for inventory of timber, wildlife habitat, and other features of interest to management and research.

Second, the characteristics within each polygon (e.g., dominant species or disturbance type) are interpreted and a general classification is assigned. **Classification** is based on convergence of evidence, meaning the interpreter uses a variety of

characteristics on the photograph to identify features on the ground (see Table 2.1). In addition to what the interpreter can extract visually, general knowledge of the area as well as on-the-ground experience with the local habitats and ecosystems contributes greatly to the interpretive process.

Table 2.1 Eight primary characteristics used in manual interpretation of aerial photographs, adapted from Morgan et al. (2010)

Characteristic	Definition	Use in manual interpretation
Tone/Color	Relative brightness or hue of pixels	Natural and anthropogenic feature identification
Size	Area (or number of pixels) of a feature or patch	Vegetation age and structure, habitat suitability, urban features/land use
Shape	Relative complexity of a feature/patch border or edge	Identification of natural (irregular shapes) and anthropogenic (geometric shapes) features
Texture	Frequency of change in tone among pixels; smoothness or roughness	Vegetation identification, biodiversity estimates, surface properties of a feature/patch
Pattern	Spatial arrangement and repetition of features or patches across an area	Land use, disturbance, habitat suitability, landscape structure
Shadow	Dark or “shadow” pixels caused by difference in elevation of a feature relative to surroundings	Feature identification and orientation
Site	Environmental conditions of the delineated feature/patch	Microclimate, species, local habitat suitability
Context	Conditions adjacent to, or surrounding, a feature or patch	Land use

EXERCISE 2: Manual Classification of Contemporary Forests

The purpose of Exercises 2 and 3 is to gain a general understanding and appreciation for the basic approach used by interpreters to analyze aerial photographs when creating forest cover maps. This exercise requires the use of colored pens and printed copies of the aerial photographs from the **OrthoPhotos** folder.

The imagery you will analyze was assembled as part of a long-term ecological research project in Clayoquot Sound, British Columbia, Canada, near Tofino, BC (Gergel et al. 2007; Morgan and Gergel 2013; Thompson and Gergel 2008). The region has changed greatly due to decades of harvest (Figure 2.3). Extensive restoration projects are currently underway in the area with a primary goal of restoring riparian forests and fish habitats. Increasing interest in spiritual and aesthetic values of these forests also supports a tourism economy. Dominant tree species can reach hundreds of years in age. Viewing the broader region in the 1970s shows the patterns of forest harvest (Figure 2.3). Using a much smaller spatial extent, you will examine forest cover change in the area using more contemporary imagery as well as historical data from several decades prior.



Figure 2.3 Regional view of the Clayoquot Sound landscape near Tofino and Ucluelet, British Columbia, surrounding the smaller area you will be examining with more recent (1990s) and historical (1930s) photographs. Here, an orthophoto has been created demonstrating landscape condition in the 70s/80s

Working as small teams (or groups of two) you will start by classifying the contemporary (circa 1996) photographs of the Kennedy Lake, British Columbia using the categories described in Table 2.2 and Figure 2.4. The area of this modern orthomosaic is 6.85 km². Read the series of steps (1–6) below, *before* you begin.

1. Within the folder entitled **OrthoPhotos**, print hard copy of the image entitled **Modern**.
2. As a first step, use a colored pen to delineate the most obviously disturbed patches. These areas might include disturbances such as roads and recently logged areas. You may also find it helpful to refer to Table 2.1 to remind yourself of the generally useful characteristics for photointerpretation.
3. Using your marker, delineate all polygons (patches) which appear visually similar.
4. Next, carefully examine Table 2.2 and its accompanying visual in Figure 2.4. Together they explain and illustrate some basic forest types found in the region.
5. Next, assign a class to each polygon. Try to discriminate late seral and second-growth forest patches. Late seral patches refer to older forest stands which have never been harvested. Second-growth stands have younger smaller trees.
6. The above exercise should take no more than 25–30 min. You will need to exercise your own judgment and make a surprising number of decisions and “rules” as you complete this task—so take good notes of any decisions you make along the way.

(NOTE: Keep in mind variation is common even amongst trained, experienced interpreters.)

Table 2.2 Basic classification scheme for **modern** aerial photographs in coastal BC

Class	Description
Water	<ul style="list-style-type: none"> • dark grey/black or light grey/white color • smooth or “flat” appearance • possibly rippled texture • rivers with linear shape • lakes with round/oblique shape
Roads	<ul style="list-style-type: none"> • distinct linear shapes • bright (white) in tone • often adjacent to (or within) harvested areas
Recently Logged	<ul style="list-style-type: none"> • lighter grey/white color • irregular shapes • sharp, well-defined borders • often adjacent to or enveloping roads
Late Seral Western Redcedar	<ul style="list-style-type: none"> • trees are light grey in color (the brightest conifer) but patches are dark due to open distribution of trees • rough texture • open distribution of trees • patch edges often occurring as gradients
Late Seral Western Hemlock	<ul style="list-style-type: none"> • lighter grey color • smooth texture • small patches with indistinct edges
Second Growth	<ul style="list-style-type: none"> • medium grey color • smooth/fine texture • smaller, inconspicuous tree crowns • often irregular shapes with fairly well-defined borders

See Figure 2.4 for examples. This classification scheme can be modified by teams as they see fit. The simplest features to interpret are general classes such as water, forest, roads, and recently logged areas. Forested areas can further be delineated into patches (or stands) based on the dominant species, age, or other forest characteristics

Once you have completed the above steps, summarize your data as suggested below:

1. Complete Table 2.3 using the row labeled **Your Team’s Result**. Remember that depending on the goals of a given project, second growth may be considered “disturbed” forest. Also, you will need to visually estimate % Landscape Disturbance.
2. Compile results on the chalkboard (in a table similar to Table 2.3), so that the results from all teams are available to the entire classroom.
3. Calculate the mean and standard deviation for the classroom and enter in Table 2.3.
4. *Only* when your interpretation is complete, examine the results of an interpretation performed by a professionally trained interpreter located in a folder entitled **Modern Interpretation**.
5. Tally results from the Professional Interpreter in Table 2.3.

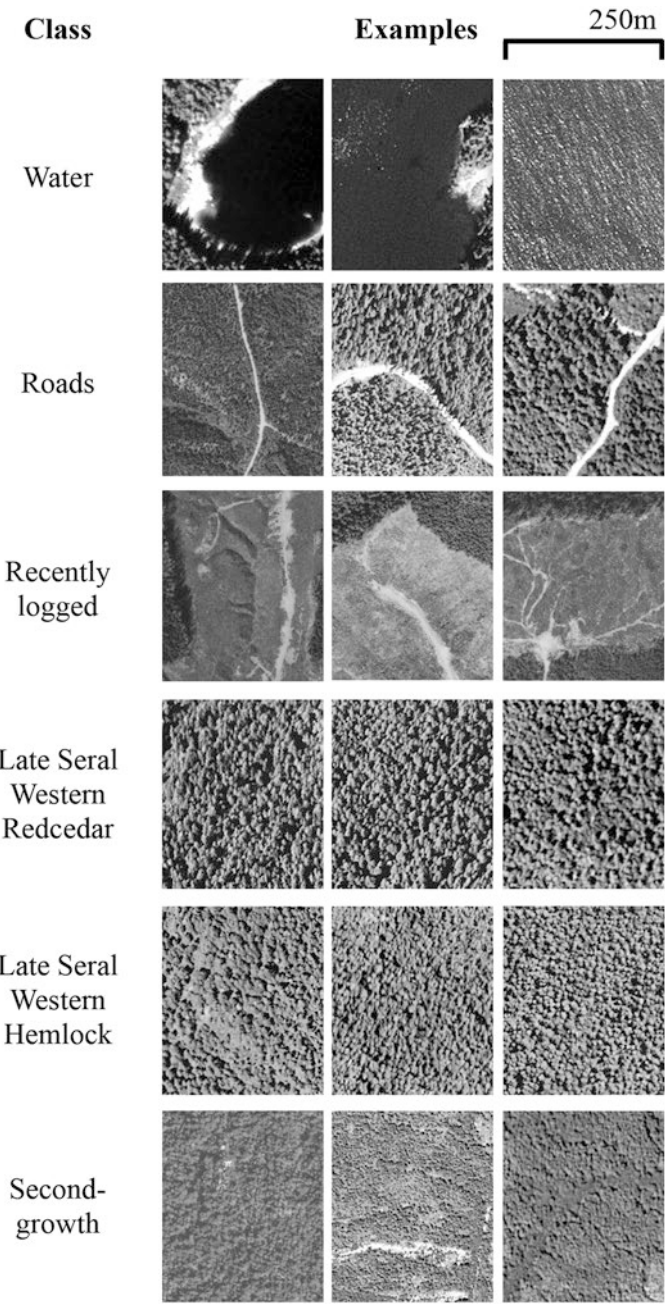


Figure 2.4 Example images for interpretation of **modern** aerial photographs. Refer to classification scheme in Table 2.2 for criteria to assist your interpretation

Table 2.3 Summary of results for **modern** aerial photograph interpretations

Modern	Number of Classes Identified	Total Number of Patches	% of Patches Disturbed	% of Landscape Disturbed
Your Team's Results				
Mean for Classroom				
Std Deviation for Classroom				
Professional Interpreter				

- Q1*** Explain some of the easier aspects of manual interpretation and also some of the challenges you encountered when using this technique. Were you forced to make some key decisions and assumptions? Explain.
- Q2*** What are the major differences between your team’s interpretation and that of the professional interpreter? What are the similarities?
- Q3*** How do the results of the professional interpreter compare to the average classroom results? What are some potential reasons for the similarities and differences?
- Q4*** Considering the standard deviation of the results (Table 2.3), what do you notice about the variability of this technique? Which measures are most and least variable (# classes, # patches, % disturbed)? What might be some reasons for this?

EXERCISE 3: Reconstruction of Historical Forests

Photographs can also be defined based on their geometry as either **vertical** (captured parallel to the ground) or **oblique** (captured at an angle). Oblique photographs captured from airborne cameras or high points on the landscape (such as mountain peaks) can predate vertical aerial photographs by several decades. However, analysis techniques for oblique photos are not nearly as well developed due to the extreme difficulty in systematically extracting information from such photographs. Historical photos, in general, can be challenging to use but do provide some unparalleled advantages for landscape analyses (Morgan et al. 2010; Morgan and Gergel 2013; Jackson et al. 2016; Nyssen et al. 2016).

For the next section of the lab, we are fortunate to take advantage of historical vertical photos which have been orthorectified to help correct for distortion and ter-

Table 2.4 Basic classification scheme for **historical** aerial photographs in coastal BC

Class	Description
Water/Wetland	<ul style="list-style-type: none">• dark grey/black or light grey color• smooth texture or “flat” appearance• linear or round/oblique shape
Low Productivity Western Red Cedar	<ul style="list-style-type: none">• light grey color• patchy or rough texture• open distribution of trees
High Productivity Western Red Cedar	<ul style="list-style-type: none">• dark grey color• coarse texture• individual tree crowns may be visible• often located in floodplains
Low Productivity Western Hemlock	<ul style="list-style-type: none">• light grey color• smooth texture• often in smaller patches
High Productivity Western Hemlock	<ul style="list-style-type: none">• medium grey color• smooth texture• small patches• often located in floodplains

rain. Here, you will conduct a manual classification at the identical location examined in Exercise 2 (also 6.85 km²) using historical photographs from 1937.

1. Utilize a printed version of the image entitled **Historical** in the **OrthoPhotos** folder.
2. Classify this image using slightly different categories, as explained in Table 2.4 and shown in Figure 2.5.
3. Using the same general approach as for the modern imagery, fill in the required information for **Your Team’s Results** in Table 2.5 based on your interpretation of the historical imagery.
4. Share your results (on the chalkboard) with the entire classroom.
5. Calculate the mean and standard deviation for the combined classroom results and enter in Table 2.5.

Q5 Again, *only when your interpretation is complete*, refer to the interpretations by trained interpreters within the **Historical Interpretation** folder and complete the last row of Table 2.5. Discuss the major similarities and differences between the interpretation of your team, the entire class, and the professional interpreter.

Q6 What challenges did you encounter when using this technique (manual interpretation) on the historic photographs? How did the process compare to the modern imagery?

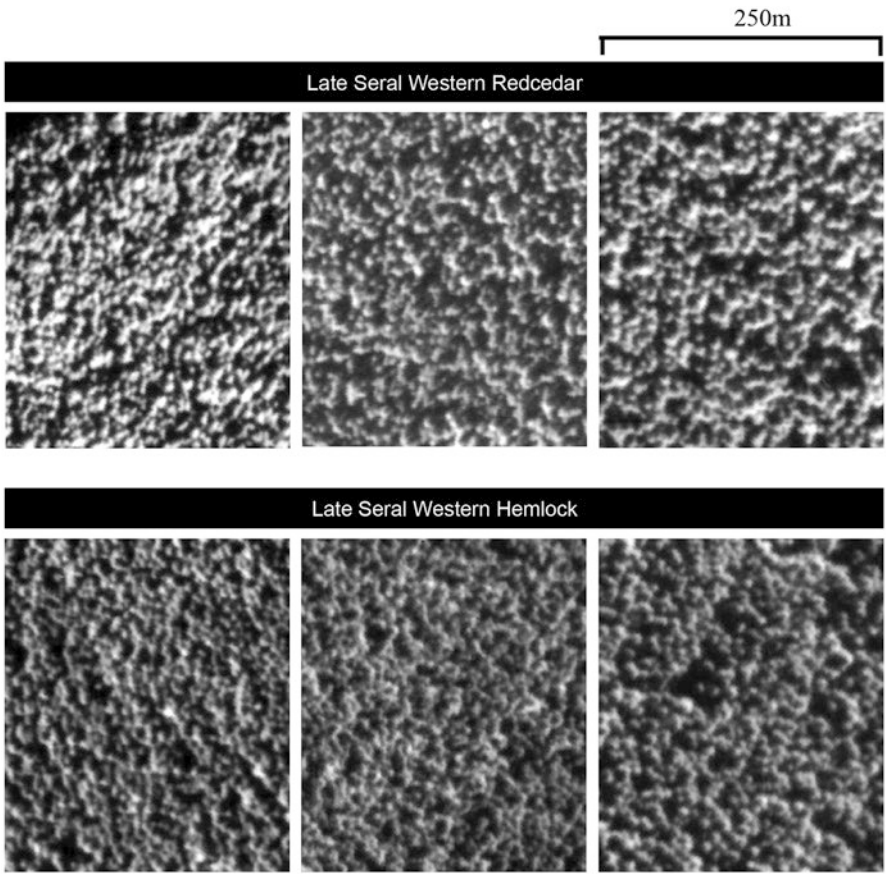


Figure 2.5 Examples of a basic classification scheme for interpretation of **historic** aerial photographs showing some subtle differences between historic forest stands of different species composition. Also see accompanying description in Table 2.4

Table 2.5 Summary of results for historical aerial photograph interpretations

Historic	# Classes	# of Patches	% Patches Disturbed	% Landscape Disturbed
Your Team’s Results				
Mean for Classroom				
Std Deviation for Classroom				
Professional Interpreter				

Q7 Which of the eight characteristics of manual interpretation (Table 2.1) were most useful in guiding your interpretation? Which of the characteristics would be the most useful to track within the context of management?

- Q8** Considering both Tables 2.3 and 2.5, what do you notice about the changes in the % of disturbed patches and % landscape disturbed between the two time periods? What are the strengths and limitations of such information for examining long-term variability in disturbances?
- Q9** Has heterogeneity changed over time in this landscape? How would you quantify heterogeneity in order to answer this question? Does your answer change when you consider “within-patch” heterogeneity as opposed to landscape heterogeneity viewed “among” different patches?
- Q10** Are the answers to the two previous questions changed greatly by the assumptions you (and other teams) made? Describe how and why.

Part 3. Additional Considerations for Improving Aerial Photo Analysis

Impact of Errors

Despite the utility of vertical aerial photographs for environmental analysis, errors can hinder interpretation and analysis (Cohen et al. 1996; Tuominen and Pekkarinen 2005). **Geometric errors** refer to positional inaccuracies which can impact both the perceived location of features as well as the size of features on a photograph (Paine and Kiser 2003; Wolf and Dewitt 2000). **Relief displacement** occurs on landscapes with high topographic variability and causes areas closer to the camera lens to appear larger than they actually are, thus misrepresenting the size of features. Before most aerial photographs can be utilized within digital applications (such as a GIS), they must be orthorectified to correct for major geometric errors and provide photographs with an appropriate spatial reference. **Orthorectification** essentially refers to the process by which vertical map coordinates (x , y , and z) are assigned to the photograph to accurately represent distances, angles, and areas (Lillesand et al. 2004). The images you used in Part 1 were stereo pairs (essentially raw imagery) whereas the imagery in Part 2 were orthorectified photographs. **Radiometric errors** refer to incorrect representation of tone/color on a photograph (Jensen 2000) and can sometimes be addressed by adjusting the contrast of the photograph.

Furthermore, errors can arise from the interpretation process. Interpretation errors can include **positional error** (errors in the location and placement of polygons), as well as **classification error** (incorrect assignment of classes). With relatively recent imagery, one can assess the accuracy of a classification through ground verification (or ground-truthing) and collect the data needed to conduct a formal accuracy assessment. When using historic imagery, however, such ground verification is often challenging, if not impossible. As an alternative to ground verification of historic imagery, we can examine uncertainty by asking a professional photointerpreter to quantify their certainty about their classification results, which we examine next.

EXERCISE 4: Uncertainty in Classification

1. Examine the images in the folder entitled **Uncertainty**. Polygons labeled 85, 90, or 100 represent those where the interpreter was confident (or highly certain) of their classification.
2. Identify the areas deemed less certain by the professional interpreter. Note any perceptible characteristics or peculiarities of these polygons.

Q11 Do these “uncertain” areas coincide with any of the areas you found trouble interpreting? Why do you think such areas were hard to interpret?

Q12 Misclassification rates for forest inventories derived from manual interpretation of aerial photography can reach as high as 60% (Thompson et al. 2007). As a team, brainstorm about some potential implications of, and solutions for, a high rate of map misclassification for resource management, conservation, and/or restoration. Prepare to share your answers with the entire class. If your instructor gives you additional time, read Thompson et al. 2007 and/or Gergel et al. 2007 for ideas.

Historic Harvest Patterns and Topography

The fundamental influence of terrain (topographic relief and landscape position) on ecological processes has long been appreciated. Despite the wealth of information obtained solely from visual (tonal, textural) characteristics of aerial photographs, additional insights regarding landscape disturbance patterns can be obtained by accounting for topography using the three-dimensional perspective obtained from stereoscopic photos. Such 3-D information can greatly help improve the process of interpretation.

EXERCISE 5: Benefits of Terrain

For this exercise, you will revisit your interpretations from previous exercises regarding forest harvest patterns. The purpose of this exercise is to understand how the inclusion of topography and terrain information can be key for understanding disturbance patterns across a landscape.

1. Familiarize yourself with the topographic data in the folder entitled **Terrain**.
2. Use the classification scheme outlined in Table 2.6 along with the topographic images, and try to identify terrain classes on your image. (This classification scheme can be applied to both the historic and the modern aerial photographs)

Q13 Can you identify any new features due to the inclusion of topography? What features now become obvious or more easily identified? Are there any changes you would make to the borders of your earlier interpretations based on these terrain classes?

Table 2.6 Topographic classification scheme adapted from the Vegetation Resources Inventory Photo Interpretation Procedures (Province of British Columbia 2002)

Class	Description
Upper Slope	<ul style="list-style-type: none">• Upper portion of a hillslope including the crest or ridge of the hill/mountain• This feature is usually convex
Middle Slope	<ul style="list-style-type: none">• Area of a slope with a straight profile• Located in between the upper and lower slope features
Lower Slope	<ul style="list-style-type: none">• Bottom portion of a hill• Usually concave and characterized by an abrupt decrease in the gradient of the hill’s slope
Flat	<ul style="list-style-type: none">• Area with a relatively flat/horizontal surface profile not adjacent to a hill base
Wetland/Water	<ul style="list-style-type: none">• Area with visible water features• Usually found in areas at the lowest relative elevation• Wetlands are often characterized by a depression (an area that is concave in all directions)

EXERCISE 6: Forest Productivity in Historical Forests

Tree height is an important characteristic used in management because not only is it associated with the general productivity of forest stands but it also influences forest structure, total biomass, potential wildlife habitat and, of course, timber. Well-trained interpreters can estimate tree height for a forest stand using stereo pairs. Most often, interpreters will assign an average tree height value within a homogeneous polygon. Productivity values can also be assigned to polygons by considering a combination of characteristics (in addition to tree height) such as soil moisture, aspect (exposure to sun), and slope.

1. Examine the contents of the folder entitled **Historical Tree Heights & Harvest Patterns** which includes photo-interpreted maps of historic productivity and tree height. Familiarize yourself with these images.
2. Using the historic **tree height** and historic **productivity** maps, determine the number of polygons with tree heights exceeding 30 m, as well as the number of polygons with productivity levels of “good” or “very good.” Enter the total number of each in Table 2.7.
3. Compare the locations of historic polygons with tall tree heights and high productivity to the same locations in the modern photograph. Using the modern photograph (and your modern interpretation), estimate how many of these historic polygons have been logged. Enter your results in the final column of Table 2.7.
4. If you find step 3 challenging, examine the file **Logging** providing an interpretation of logging (based on the modern photo) located in the same folder.

Table 2.7 Summary of results for historic forest productivity and subsequent logging patterns according to topography

Topographic Class	Historic productivity		Subsequent harvest	
	# Polygons	# Polygons	# Polygons	# Polygons
	Tree heights >30 m	Good or very good	(from column 1) logged	(from column 2) logged
Upper Slope				
Middle Slope				
Lower Slope				
Flat				
Wetland or Water				

Topographic classes are explained more fully in Table 2.6

- Q14** What trends in logging patterns do you notice from the results in Table 2.7?
- Q15** Consider some potential ecological (or other) consequences of these patterns of historic harvest. Explain two potential implications for management.
- Q16** Discuss how your results are influenced by the uncertainty maps from Exercise 4. Are you more or less confident of your results and interpretation after incorporating the uncertainty maps?

SYNTHESIS

- Q17** Consider a landscape you know well. Perhaps it is close to your home or where you have done research. Devise an interesting question for this area utilizing historical aerial photography. Explain why your question is important and briefly explain your expected results (your proposed hypotheses). Explain how aerial photographs (and any auxiliary datasets) would be used in the project.

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¹NOTE: An asterisk preceding the entry indicates that it is a suggested reading.

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