A Web-based Time Machine

picturing two centuries of landscape change

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LS 6164

Ever wondered what landscapes of 100 years ago looked like? The *Landscape Change Program* is a web-based, NSF-supported community archive of Vermont landscape imagery that answers this question.

The Program provides primary data (images of past landscapes) useful for understanding and managing present-day landscapes. The archive contains thousands of images collected from or contributed by a variety of sources, all available free-of-charge, on-line at *uvm.edu/perkins/landscape*. Many of these images show both geologically- and landscape management-relevant subjects including floods, landslides, deforestation, reforestation, development, road building, and erosion.

Rephotography of archive images shows dramatic changes. For example, rephotography of a very early set of more than 60 oblique aerial photographs taken along river corridors just days after the flood of record for most of Vermont (1927), documents dramatic revegetation as well as floodplain and near-river development patterns over the past 75 years. Numerous images of gully erosion and shallow landsliding support the conclusion that clear cutting of New England slopes led to widespread increases in sediment yield, as once-forested but then-cleared hill slopes, failed. Examining photographs that include riparian corridors is a useful way of estimating change in stream-side vegetation density and structure over time.

The *Landscape Change Program* provides a public, visual means for people to explore the complex inter-relationships between geology, geomorphology, human activity, and landscape change over time. We hope that the archive will serve as a model for investigators in other states to compile similar databases.

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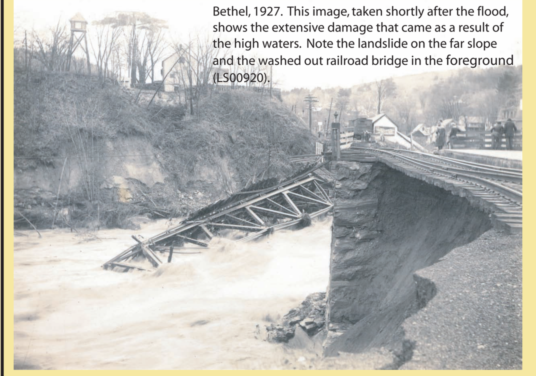
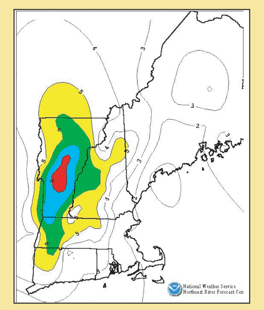
Rivers -- The 1927 Flood of Record

In 1927, a flood several times larger than any other recorded event, struck Vermont. The flood occurring over November 2, 3, and 4 destroyed over 1000 bridges and caused significant channel change and channel bank erosion. Flood levels varied from 15 to 30 feet above normal. Since 1927, Vermont has been re-forested, river channels have changed course, and development has altered the landscape greatly. Modern rephotography of flood and post-flood images in the archive allow us to quantify the changes that have occurred since 1927. Such quantification includes measuring channel roughness at different flows and documenting channel change. **The archive images viscerally demonstrate the hazard posed by rare but severe floods.**

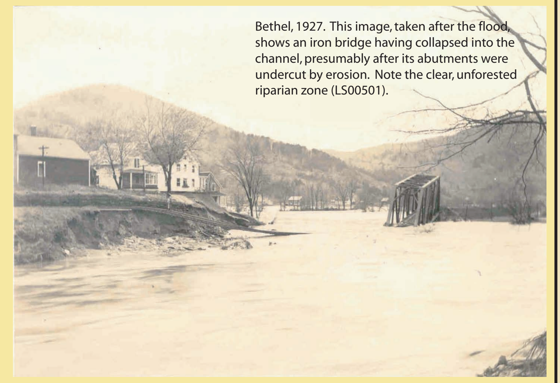
Rephotographing the '27 Flood Images



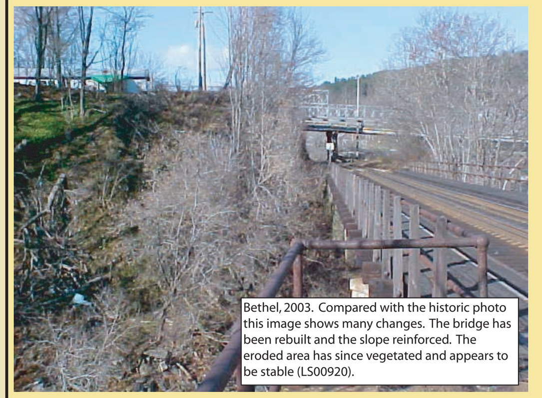
Bethel, 1927. This image, taken shortly after the flood, shows the extensive damage that came as a result of the high waters. Note the landslide on the far slope and the washed out railroad bridge in the foreground (LS00920).



The '27 flood resulted from an unusual late-season incursion of tropical moisture overrunning the Green Mountains. October 1927 had been very wet with 150 to 300% of normal precipitation, leaving soils saturated. The storm dropped up to 9" of rain in central Vermont with more than 5" falling over most of the state. Storm totals are mapped to the left.

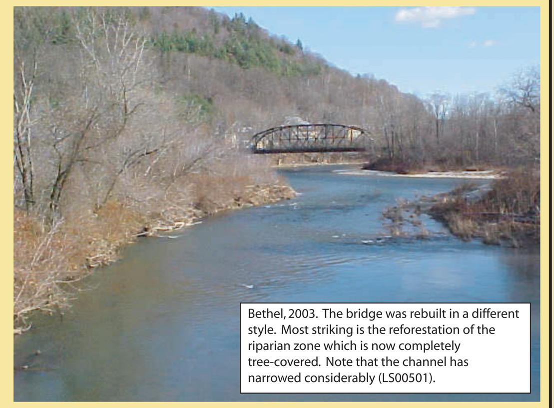


Bethel, 1927. This image, taken after the flood, shows an iron bridge having collapsed into the channel, presumably after its abutments were undercut by erosion. Note the clear, unforested riparian zone (LS00501).

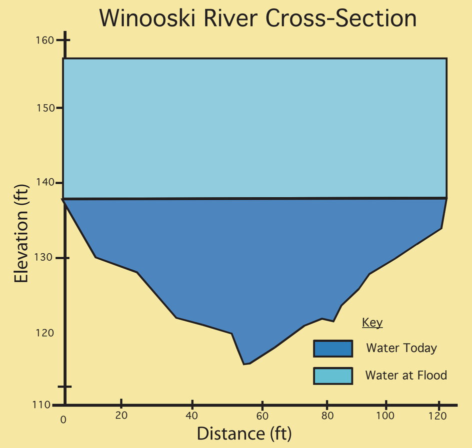


Bethel, 2003. Compared with the historic photo this image shows many changes. The bridge has been rebuilt and the slope reinforced. The eroded area has since vegetated and appears to be stable (LS00920).

Proctor, Vermont was particularly hard hit. Otter Creek overflowed its banks and cut this new channel through till and alluvium down to the underlying rock (LS00115).



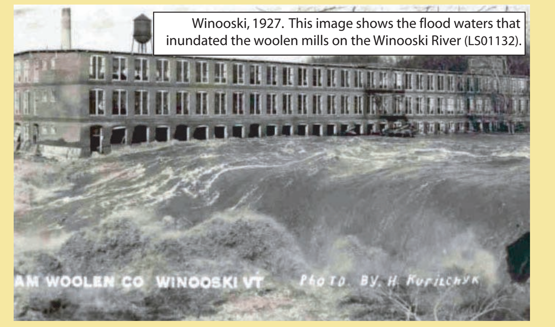
Bethel, 2003. The bridge was rebuilt in a different style. Most striking is the reforestation of the riparian zone which is now completely tree-covered. Note that the channel has narrowed considerably (LS00501).



We used historic imagery, discharge records, and a modern day survey to back calculate channel roughness during the flood of 1927 at the Winooski Mills, pictured here. The historic photo allowed us to estimate river height and thus calculate roughness at flood stage; modern-day channel geometry and discharge allow us to estimate roughness at lower flows.

Flood discharge: 118,000 CFS (Winooski Dam)
Flood roughness = 0.020

Typical discharge: 18,000 CFS (Winooski Dam)
Low flow roughness = 0.017

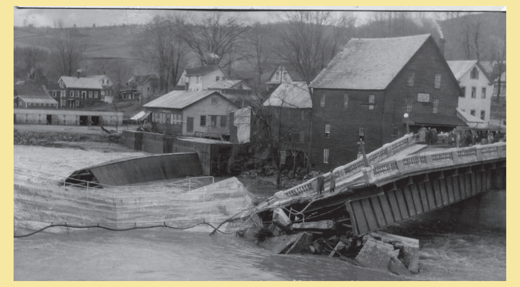


Winooski, 1927. This image shows the flood waters that inundated the woolen mills on the Winooski River (LS01132).

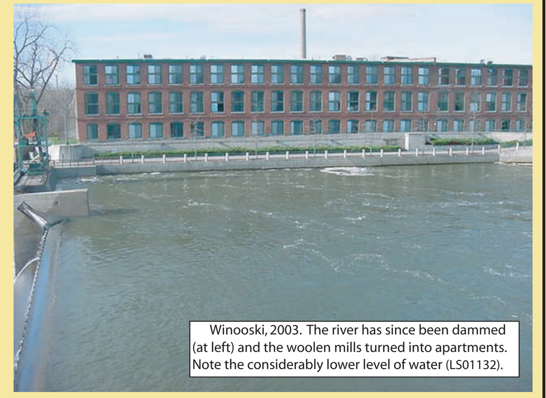
Manning's Equation

$$V=(R^{2/3} \times S^{1/2}) / n$$

V = average velocity, m/second.
R = hydraulic radius (area/wetted perimeter)
S = slope of water surface
n = roughness coefficient.



A newly built bridge in Randolph, destroyed by the flood of 1927. One of the more than 1000 Vermont bridges lost in only a few November days (LS00659).

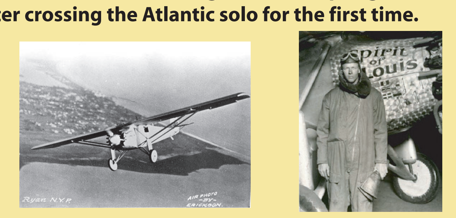


Winooski, 2003. The river has since been dammed (at left) and the woolen mills turned into apartments. Note the considerably lower level of water (LS01132).

Rephotographing Vermont 77 years after the Flood of '27

Within days of the devastating flood, the US Army flew over Vermont photographing the damage. Of the 90 images taken, 67 are extant. During the summer of 2004, these 67 were rephotographed to show the changes in riparian corridors, development, and channel characteristics. Curiously, just months before the flood, Lindbergh came to Springfield, VT after crossing the Atlantic solo for the first time.

Montpelier, 2004. Much has changed since 1927. The area has not only been significantly reforested, but also extensively developed. The river has changed little, aside from an increase in riparian vegetation (LS01429).

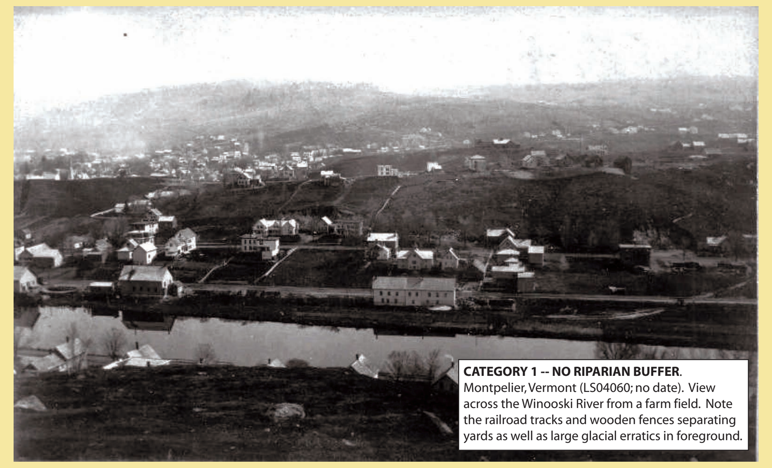


from the US Library of Congress

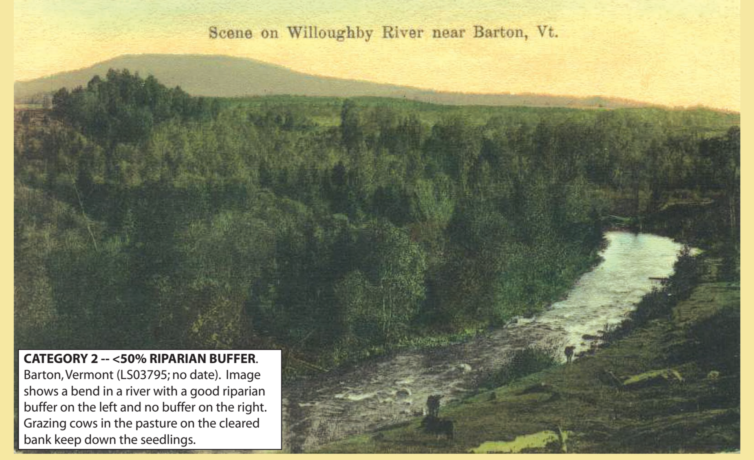
Montpelier, 1927. Using aerial photographs allows evaluation of a large area. As can be seen in this photo (taken days after the '27 flood) much of the area has been deforested, the flood waters reached far up on the near bank (LS01429).

Riparian Buffers -- Coming back

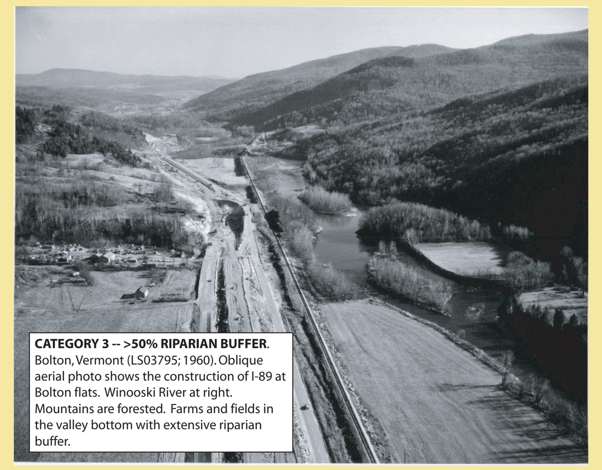
Vermont has not always been the Green Mountain State. In the late 1800s, Vermont's hills and valleys were over 70% deforested, the legacy of timber harvests and agriculture. Trees growing alongside rivers were susceptible to removal because they were easily transported, often close to major towns, and covered rich floodplain soils ideal for farming. **We analyzed over 400 photographs of streams and rivers from the *Landscape Change Program* archive and find that the quality of riparian buffers has improved over time.** Since the mid 1800s, the incidence ofcompletely barren riparian zones has decreased. The most rapid increase in riparian vegetation occurred in the 1980s, about 20 years after community forests were planted, the environmental movement started, and the decline of the Vermont dairy farm began.



CATEGORY 1 -- NO RIPARIAN BUFFER. Montpelier, Vermont.

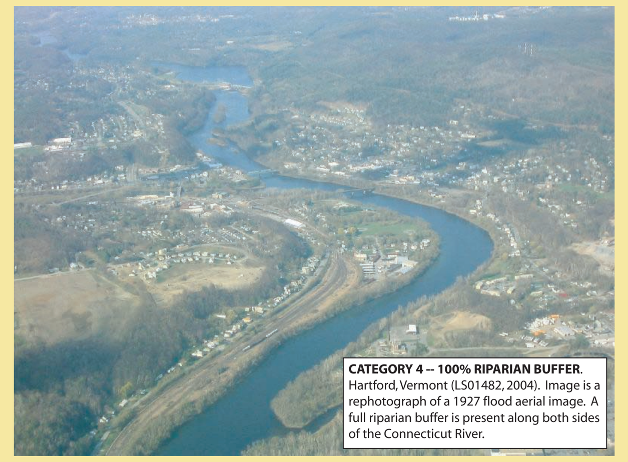


CATEGORY 2 -- <50% RIPARIAN BUFFER. Barton, Vermont.

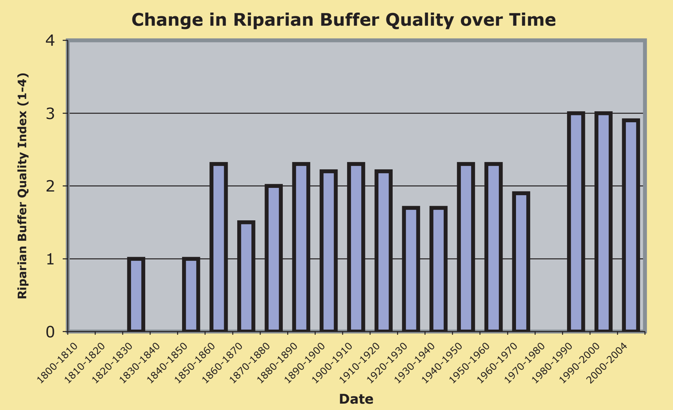


CATEGORY 3 -- >50% RIPARIAN BUFFER. Bolton, Vermont (LS03795; 1960). Oblique aerial photo shows the construction of I-89 at Bolton flats. Winooski River at right. Mountains are forested. Farms and fields in the valley bottom with extensive riparian buffer.

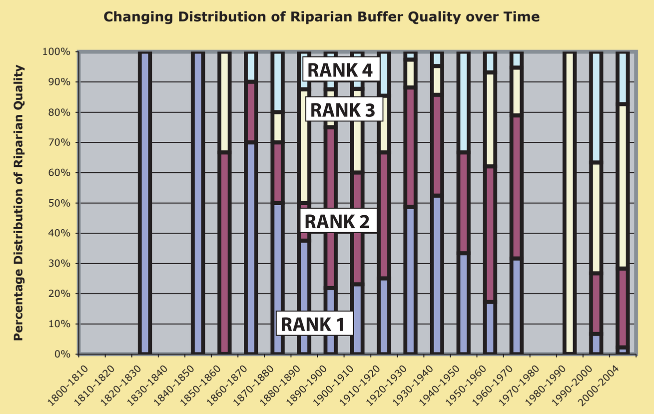
We searched the *Landscape Change Program* archive for all images that showed riparian buffers and found >400 usable images. We ranked the condition of the riparian buffer in each image using four categories as illustrated by these images.



CATEGORY 4 -- 100% RIPARIAN BUFFER. Hartford, Vermont (LS01482, 2004). Image is a rephotograph of a 1927 flood aerial image. A full riparian buffer is present along both sides of the Connecticut River.



We defined a riparian buffer quality index based on the scale shown above and used it to rank every image. Sorting the images by decade, we calculated an average quality index for every ten-year interval. **We find that between 1850 and 1970, the index varied between 1.5 and 2.3; then, after 1980 the index rises to about 3, a significant increase.**



The distribution of riparian zone quality in Vermont has changed through time. The prevalence of river margins with no buffer at all decreased between 1850 and today. In the last 25 years, the prevalence of river margins with greater than 50% tree cover has increased. **The quality of riparian buffer zones has improved in the past several decades.**

What caused the return of riparian buffers?

BEFORE 1700 – Virgin forests cover state
1760 to 1800 – European settlement
1780 – Clearing of land for agriculture and timber
1791 – Industrial Revolution in Vermont (textile mills, factories)
1811 – Introduction and boom of Merino sheep farming
1840s – Decline of sheep farming
1860s – Burlington fourth largest lumber port in US
1870 to 1880 – Maximum number of farms in state (68% of land)
1890s – 70% of land deforested
1920s – Municipal forests created; local tree planting initiatives
1928 – Purchase of first Green Mountain National Forest
1930 – Long Trail completed
1938 – Flood Control Act- USDA control over soil erosion, water flow
1940s and 50s – Forestry programs initiated for recreation
1950s – Rise of ski industry in VT
1960s – Rise of national, local environmental organizations
1960S to TODAY – Steady decline in dairy farms
1980s – Vermont 70% forested

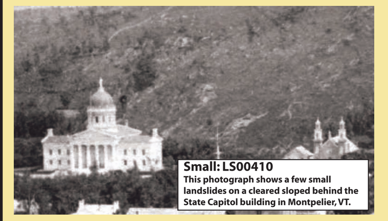
Log mill and log drive in Sharon, Vermont (LS2110; 1910) showing large numbers of logs in the river channel and stripped riparian zones.

Erosion -- The Tree Connection

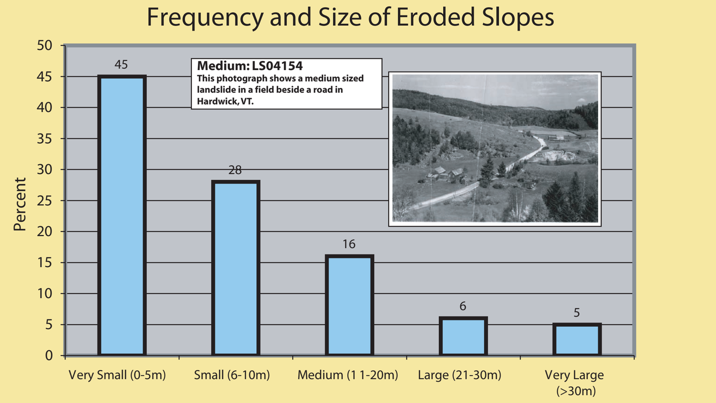
Our goal is to compile visual evidence that clear cutting is coincident with erosion in Vermont. To achieve this goal, we searched the *Landscape Change Program* archive of over 7,000 images using the keywords: clear-cutting, landslides, and erosion. From the search results, we categorized images with respect to the amount of tree coverage, the size of the eroded area, and other landscape characteristics including clear-cut slopes, roads, and farming. **From the analysis of these images, we conclude that clear-cutting and the removal of woody vegetation increased the frequency of erosion and landslides in Vermont.**

Frequency and Size of Eroded Slopes

Very Small: LS06469 This image is a hand colored lanternslide of a horse and buggy on a washed out road in St. Johnsbury, VT from 1914.

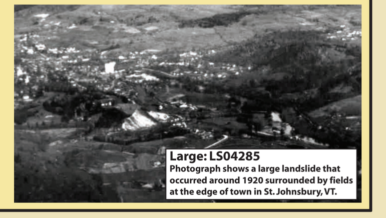


Small: LS00410 This photograph shows a few small landslides on a cleared sloped behind the State Capitol building in Montpelier, VT.



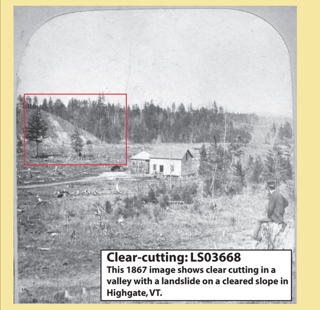
We classified erosion into five different categories depending on the size of the eroding area. Small areas of erosion are much more common than large areas of erosion.

Very Large: LS01781 This photograph shows a very large landslide that occurred in Burlington, VT in December of 1955.

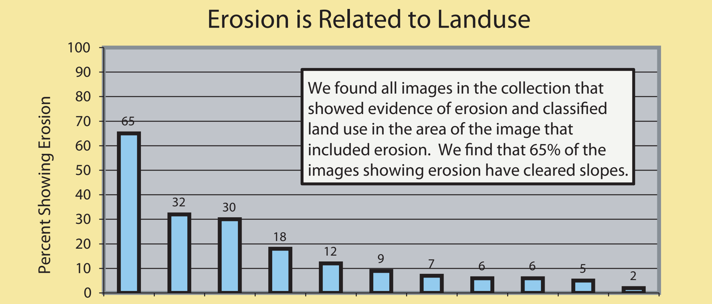


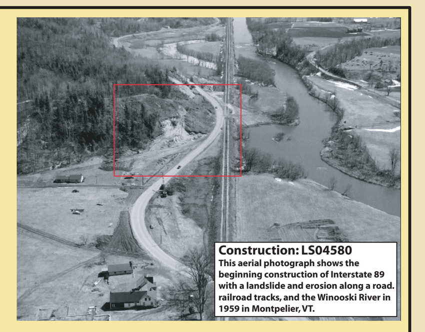
Large: LS04285 Photograph shows a large landslide that occurred around 1920 surrounded by fields at the edge of town in St. Johnsbury, VT.

Erosion is Related to Landuse

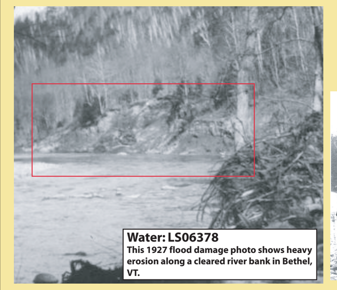


Clear-cutting: LS03668

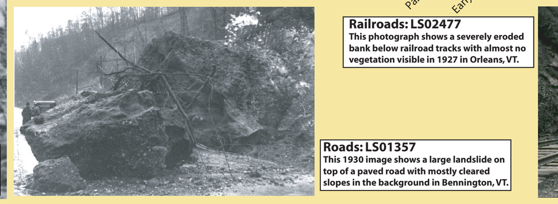




Construction: LS04580

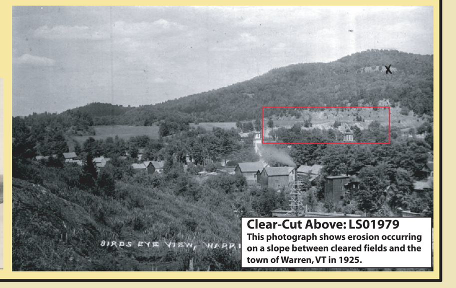


Water: LS04378

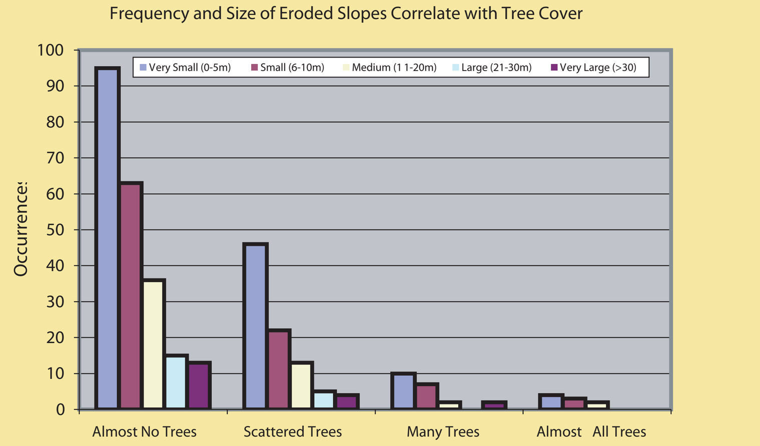


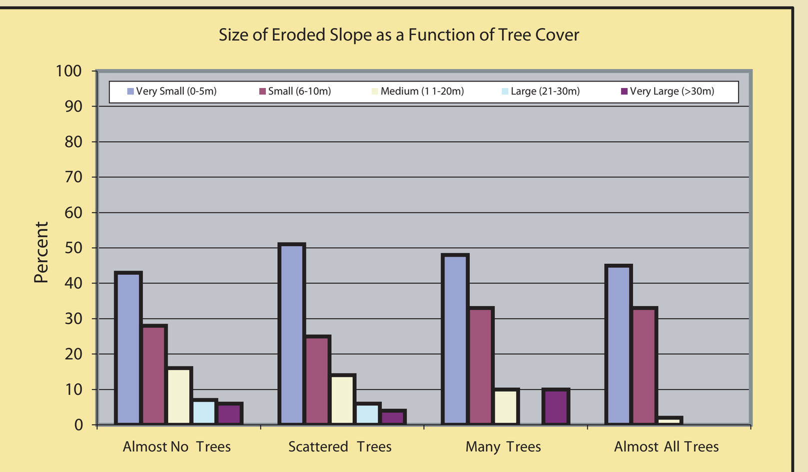
Railroads: LS02477

Roads: LS01557



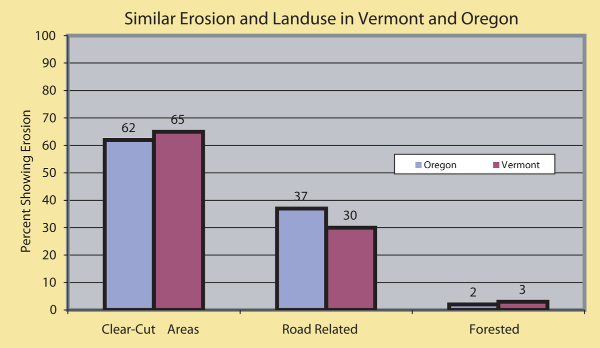
Clear-Cut Above: LS01979





We find a strong inverse relationship between landscape tree cover and the number of images showing erosion. Of the 342 archive images showing erosion, 222 had no trees or almost no trees near the eroded site. Conversely, only 9 images showing erosion had full tree cover near the eroded site. There is a smooth trend of increasing tree cover and decreasing erosion. **Smaller areas of erosion are always more common than larger areas of erosion, no matter what the tree cover.** If we normalize for the frequency of landslides in each tree cover class, the size distributions of erosion areas are remarkably similar.

Clear-cutting and Road Building Catalyze Erosion



We find a distinct relationship between land use and erosion. Examining the 342 images in the *Landscape Change Program* archive that show erosion, we find that in 65% of these images, erosion occurs in clear-cut areas. Only 3% of images showing erosion have complete forest cover. Data from Vermont spanning nearly 150 years, give very similar results to data collected in the Willamette National Forest in Oregon after a major 1996 storm. **Both data sets suggest that people catalyze soil erosion by clearing slopes and building roads.**