Baker Bay Area, WA, Timber Harvest Change Detection Using Unsupervised Classification

An Analysis by Skyler Elmstrom for ESCI 442

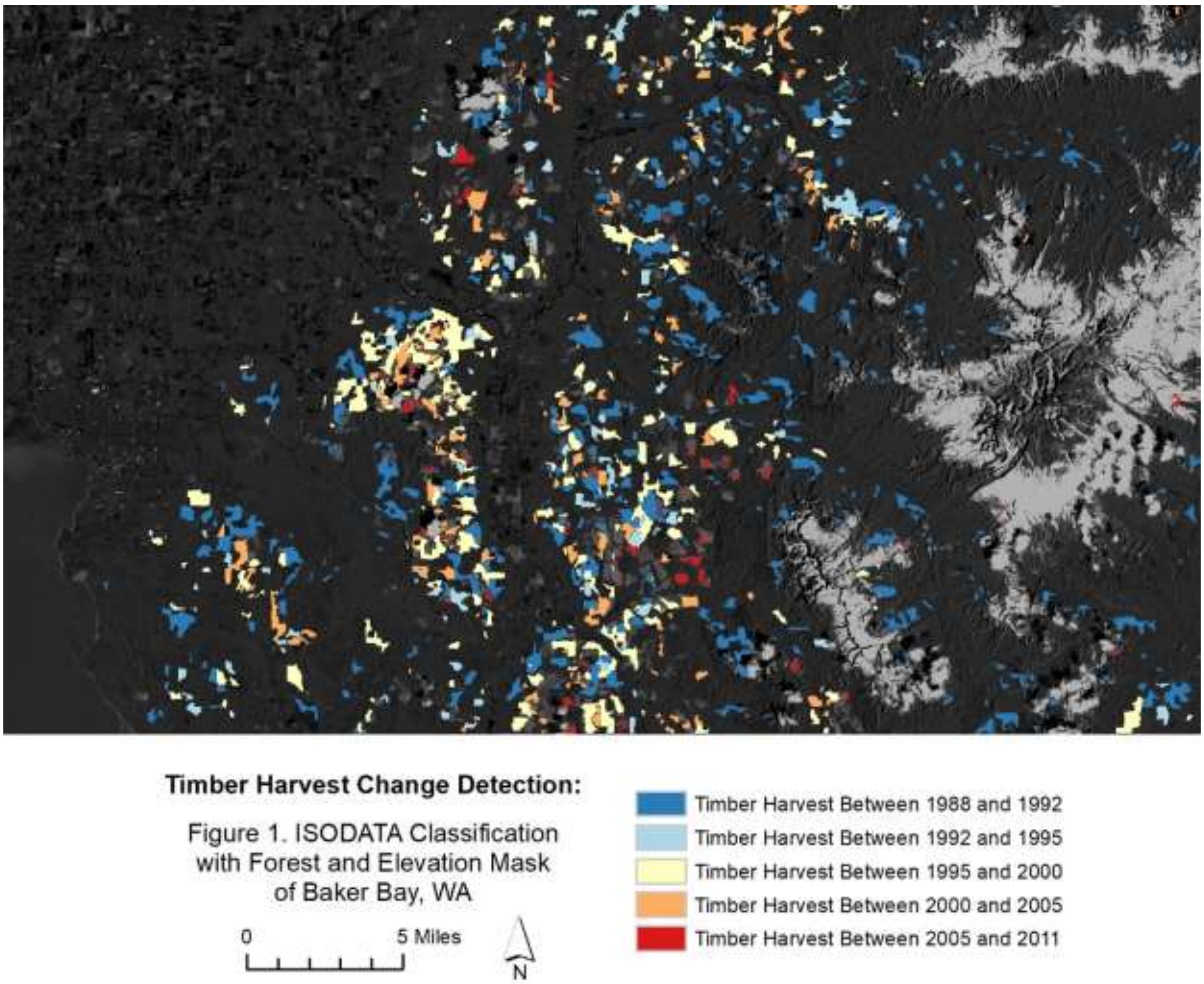


Figure 1. ISODATA Classification with Forest and Elevation Mask of Baker Bay, WA

Abstract

The collectively consistent and global dataset from LANDSAT remote sensing satellites has provided resource managers with the ability to assess land use over time since 1972. In this study, I utilized six LANDSAT scenes from five periods ranging from 1988 to 2011 to identify forest harvest areas and cross-referenced them with property ownership boundaries of DNR, USFS, private, and wilderness to approximate harvest rates by each ownership. My analysis suggests that there has been a significant decrease in harvest rates during the study period—roughly 92.3%. DNR and private lands had the highest percentage of exploited forest lands, but all ownership groups saw significant reductions in timber land exploitation which was likely due to changing forest management practice and policy, economic supply and demand, and public opinion. While this study was useful for determining trends, rigorous accuracy assessment for harvest areas was not possible due to limited ground-truth datasets and the absence of the use of historical timber harvest records as a cross-reference in this study.

Introduction

Satellites have revolutionized our daily lives; their presence —and their usefulness— has trickled into nearly every sector of business and industry. Since the launch of the first LANDSAT, a remote sensing platform, we have also acquired a unique view into the past: a consistent and global dataset from 1972 to present —a boon to resource management. In this application, I investigated the potential for timber harvest monitoring across time using LANDSAT scenes captured in 1988, 1992, 1995, 2000, 2005, and 2011. Utilizing ISODATA unsupervised classification methods and several post-processing algorithms in Harris Geospatial's ENVI, I was able to calculate approximate harvest areas and harvest rates for Department of Natural Resources (DNR), national forest managed by the United States Forest Service (USFS), private, and wilderness lands.

Methods

The methods of this change detection analysis are based on guidance and instructions from Wallin (2018a, 2018b) —Lab III and Lab IV— and consist of three general steps.

Change Detection & ISODATA Classification for 1988-2011 LANDSAT Scenes.

Before running an ISODATA classification, a change detection raster for the 1988-2011 LANDSAT scenes was created using a tassel cap transformation emphasizing brightness value subtractions from 2011-2005, 2005-2000, 2000-1995, 1995-1992, and 1992-1988, and similarly, greenness value subtractions with the same ranges (Wallin 2018b). The result of these differences serves as my change raster. The 2005-2011 brightness difference can be seen in the background of Figure 1 in greyscale. I then ran an unsupervised ISODATA classification on the change raster and created 6 information classes: no change (black, 0-value) and timber harvest from 1988-1992; 1992-1995; 1995-2000; 2000-2005; and 2005-2011 (Figure 2).

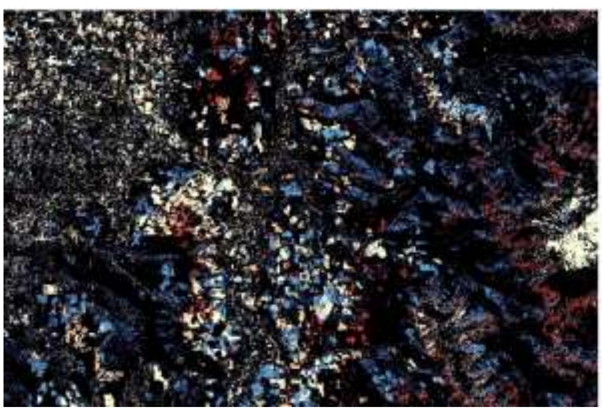


Figure 2. ISODATA classification of tassel cap transformation difference raster. Harvest areas are color-coded by period.

Masking Non-forested, Agricultural, and High Elevation Areas.

I used a classified image of the 2011 Baker Bay area I had made previously for creating a forest mask to be used in my change detection analysis. I consolidated the forest classes and removed all other classes that are non-forested areas (Figure 3). This mask will primarily be used to reduce the number of "harvested forest" areas that occur in non-forested areas such as urban and agricultural areas. I also created an elevation mask that excludes values below 100 meters and above 1700 meters to eliminate the possibility of harvest areas occurring above the timberline and agricultural areas being misclassified as timber harvest. The forest and elevation mask were then multiplied by each other to create the combined mask that I used for masking my ISODATA classification (Figures 4 and 5).

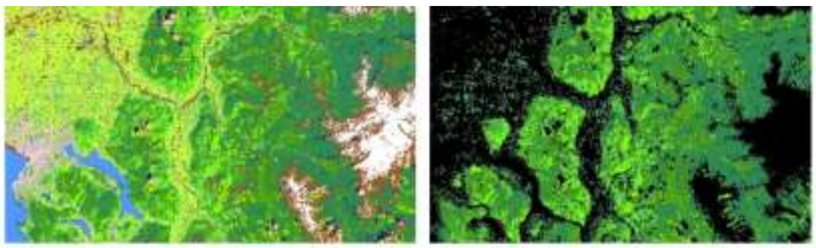


Figure 3. ISODATA classification of 2011 Baker Bay Area LANDSAT scene (left), and forest only classes (right) mask for forest land in the change detection analysis of Baker Bay Area from 1988-2011.

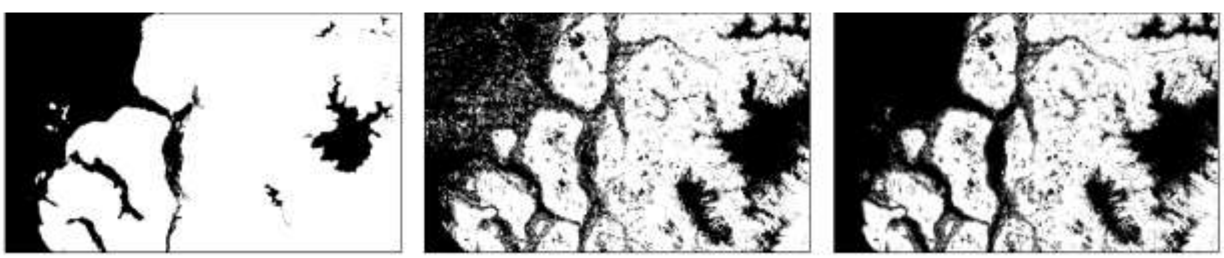


Figure 4. Elevation mask (left), forest mask (center) and a combined elevation and forest mask (right).

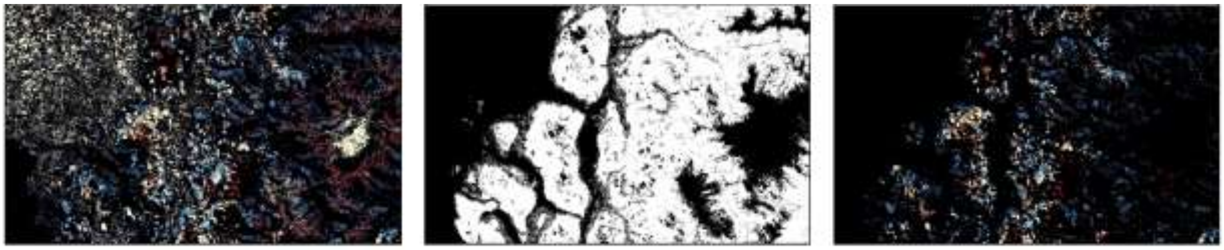
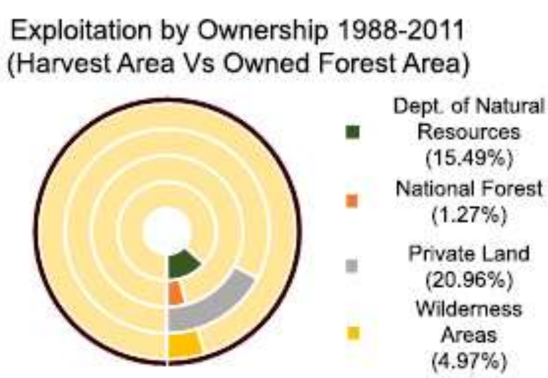


Figure 5. Initial ISODATA classification (left), elevation and forest mask (center), and result of mask and post-processing to fill holes in harvest areas and reduce noise (right).

Calculating Harvest Area

After masking and post-processing my harvest area ISODATA classification, I ran additional band math processes in ENVI to create a new raster with ownership-differentiable harvest areas based on forest area ownership as specified in Wallin (2018b). I generated statistics for this harvest area ownership raster to provide pixel counts of harvest areas by period and by ownership using the ENVI quick stats function. Additionally, I generated statistics for the forested area mask I created for use in determining rates of harvest compared to total forest area. Pixel counts from the generated statistics then were used to calculate forest area harvested during each harvest period, an approximate rate of forested area harvested per year, and an approximate rate of forest area harvested per year by ownership.

Results

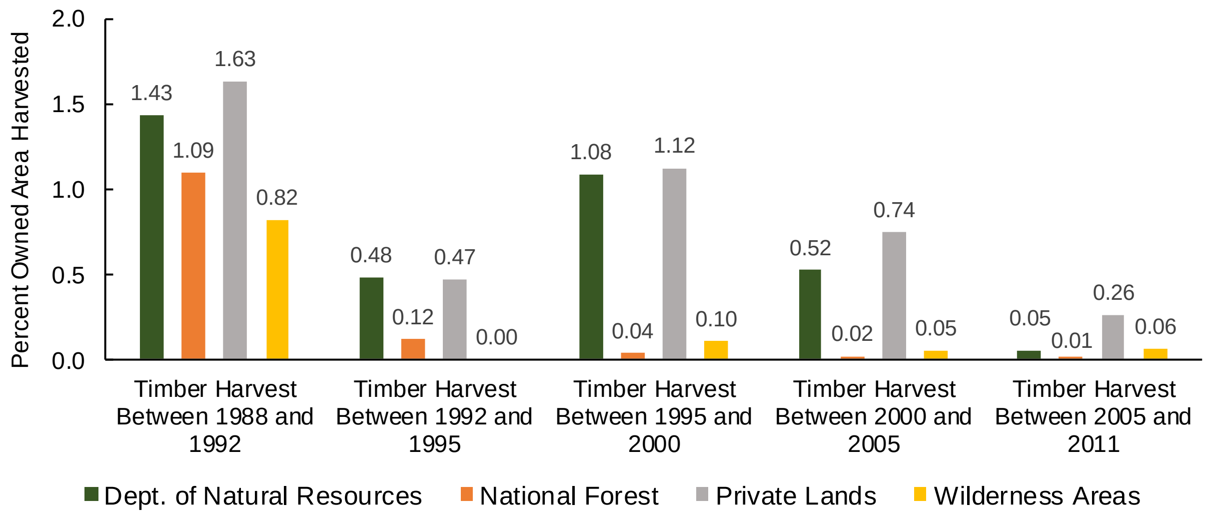


The results of my analysis show that from 1988-2011, approximately 17,359.3 ha out of the 124,578.1 ha of total forested area — 13.93% of the total forest inventory— was exploited by the four ownership groups being inspected: DNR, National Forest, private, and wilderness areas (Table 1). The highest exploitation was seen in private lands (20.96%) and the lowest was seen in National Forest (1.27%). There is a clear downward trend in harvest rate per year for each ownership group and their forest inventory between 1988 and 2011: DNR rate of harvest in 2011 was about 3.5% of their 1988 rate; National Forest' 2011 rate of harvest was less than 1% of the 1988 rate; private lands' 2011 rate of harvest was 16% of the 1988 rate; and wilderness areas' 2011 rate of harvest was 7% of the 1988 rate (Figure 7). Overall, DNR lands had an average harvest rate of 0.67% per year; National Forest had an average of 0.18%; private lands had an average of 0.91%; and wilderness areas had an average of 0.21%.

Table 1. Approximate Total Harvest Area (Hectares) By Period

Period	Dept. of Natural Resources	National Forest	Private Lands	Wilderness Areas
Timber Harvest Between 1988 and 1992	1981.1	1091.6	3962.4	323.2
Timber Harvest Between 1992 and 1995	498.9	194.1	1141.6	0.0
Timber Harvest Between 1995 and 2000	1876.6	59.1	3274.4	33.2
Timber Harvest Between 2000 and 2005	905.6	39.6	1449.1	12.4
Timber Harvest Between 2005 and 2011	105.6	6.9	380.3	23.8
Total Harvest Area of All Periods	**5367.8**	**1391.3**	**10207.8**	**392.5**
Total Forested Area	34648.9	33324.9	48701.4	7902.9

Figure 7. Percent Harvest Rate of Owned Forest Per Period Per Year



Discussion

The timber industry has historically gone through a cycle of boom and bust in response to demand from its customers. The Pacific Northwest (PNW) saw its largest modern timber boom in the late 1970's and early 1980's as well as the rise of prominent environmental lobbyists and interest groups. In response to the destruction of much of Washington's old growth forests, timber industry policy makers began creating more regulations to protect and preserve forest for habitat for endangered species, recreational use, and wilderness areas. The decline of the timber industry in the PNW following the early 80's was widely blamed on the Endangered Species Act of 1973 and the addition of the Spotted Owl to the list of species under its protection, but other economic sources of decline such as competition with Canada, a reduction in demand as construction slowed in the U.S., environmental policies that reduced the amount of timber that could be harvested in National Forests, overharvesting of timber lands, and mechanization and technology may have also played a significant role (Vero 2018 and Seeing 2018). Since 1998, several species of important trout and salmon were also added to the ESA list, further complicating the struggle for managing timber harvest in the PNW (Seeing 2018).

My analysis seems reasonable given the trends described in literature of declining rates of harvest in my study area. Additional literature could be used to explain the small increase in harvest during the 1995-2000 period, but generally I observed a downward trend from 1988-2011. Privately owned timber areas are intensively managed for growing and harvesting timber by large lumber corporations such as Weyerhaeuser and DNR lands are also managed for timber harvesting to provide public funds, so the higher rates of harvest in these areas are expected (Wallin 2018b). Congressionally-declared wilderness and National Forest protection policies limit timber harvest in these areas (Wallin 2018b); my analysis supports the trend of limiting harvesting.

Unlike my previous analysis that classified the Baker Bay area using reference data collected from students with handheld GPS units following the instructions provided by Wallin (2018a), this analysis did not have any ground-truth data associated with the scenes being used. Obtaining ground-truth data in this case is not feasible given we'd need to access dangerous, remote, and mostly private property. However, if another agency or university has compiled data on timber harvest areas, it could potentially be used to improve this analysis. It is difficult to assess the accuracy of this analysis and my quality checks were primarily based on visual inspection and subjective interpretation of information classes. My analysis does not identify natural disturbance versus timber harvest disturbance, but this may be difficult to expand upon with only 6 LANDSAT scenes being used as disturbance such as fire, flood, landslide, and harvest may appear similar after the recovery stages of succession take hold of an area; this would require seasonal images for each year in the study period and perhaps some ground-truth training data for each type of disturbance. Another source of error comes from the masks I used to simplify my analysis. My forest mask was based on an unsupervised ISODATA classification as described by Wallin (2018a) and my combined forest classes had an accuracy of about 85%, so there is a small chance that some forest areas were cropped out of the final analysis. Additionally, my elevation mask assumed no timber harvest was occurring below 100 meters or above 1700 meters; this generalization may not be true in all locations of my study area and will introduce varying amounts of error. If I were to repeat this analysis, I would mask my image with the combined forest and elevation mask prior to running my unsupervised ISODATA classification. This rearrangement in procedure assist the final analysis two-fold: masking before classification decreases the spectral variability of my image and allows me to create more narrowly focused initial information classes and would save time during my subjective reclassification of the ISODATA classes by eliminating confusion classes that appear to have similar amounts of brightness/greenness change such as alpine/snow and agricultural areas or intertidal areas and bare ground.

Conclusion

My analysis appears to correlate strongly with the historical context of the state of the PNW timber industry: strong downward trends in harvest rates are occurring in all areas from 1988-2011 and are likely due to significant alterations to forest management policy, public opinion, and economic supply and demand. The accuracy of my area analysis has some flaws, but overall captures the general trends discussed in the literature. I believe this analysis could be improved by running a mask before classifying the brightness/greenness change raster and cross-referencing the resulting timber harvest areas with existing data from other sources for an accuracy assessment.

Sources

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