

Assessing Landscape Transformation in Western North Carolina Due to Hurricane Helene 2024 Using Sentinel-2 High Resolution Multispectral Imagery

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Key Judgements

- SVM produced the most reliable post-storm classification, achieving an Overall Accuracy of 97.5% and a Kappa coefficient of 0.967 after Hurricane Helene. Highest post-storm performance of all three classifiers tested.
- SVM and RT confirmed Artificial surface loss and Baren Land expansion after Helene, indicating widespread infrastructure destruction and sediment deposition. ML detected no meaningful change in Artificial Surfaces (+0.40 percentage points).
- ML was the only classifier where the accuracy declined after the storm, with Kappa dropping from 0.944 to 0.841 and Artificial surfaces User, accuracy declining to 33.3% indicating spectral confusion under post-flood conditions
- All three classifiers achieved reliable pre-storm classification (Kappa 0.863-0.944); post-storm reliability deviated, with SVM and RT improving while ML declined.
- No single classifier captured the full scope of landscape transformation; combining multiple classifiers provides the most complete post-disaster assessment.

Introduction

Hurricane Helene caused flooding across Western North Carolina (WNC), severely impacting infrastructure, ecosystems, and communities along the French Broad River, Swannanoa, and Broad River. This study applies three supervised techniques Maximum Likelihood (ML), Support Vector Machine (SVM), and Random Trees (RT) to Sentinel-2B multispectral imagery from before (October 13, 2023) and after (October 7, 2024) the hurricane to quantify landscape transformation across a study area of 430 km² to evaluate which method best supports post-disaster flood mapping.

Background

WNC is a mountainous, heavily forested region with numerous river systems subject to orographic rainfall. The three rivers, French Broad, Broad, and Swannanoa, experienced record flooding during Helene, resulting in infrastructure destruction,

landslides, and significant sediment deposition. Two Sentinel- 2B level 2A tiles (orbit 140) were utilized and atmospherically corrected for surface reflectance products at a 10-meter spatial resolution across Bands 2, 3, 4, and 8 (Blue, Green, Red, and NIR). Imagery was clipped to a 0.5-mile buffer around the three river corridors, covering 4,300,024 pixels (430km²). Four land cover classes assessed were water, artificial surfaces, vegetation, and barren land.

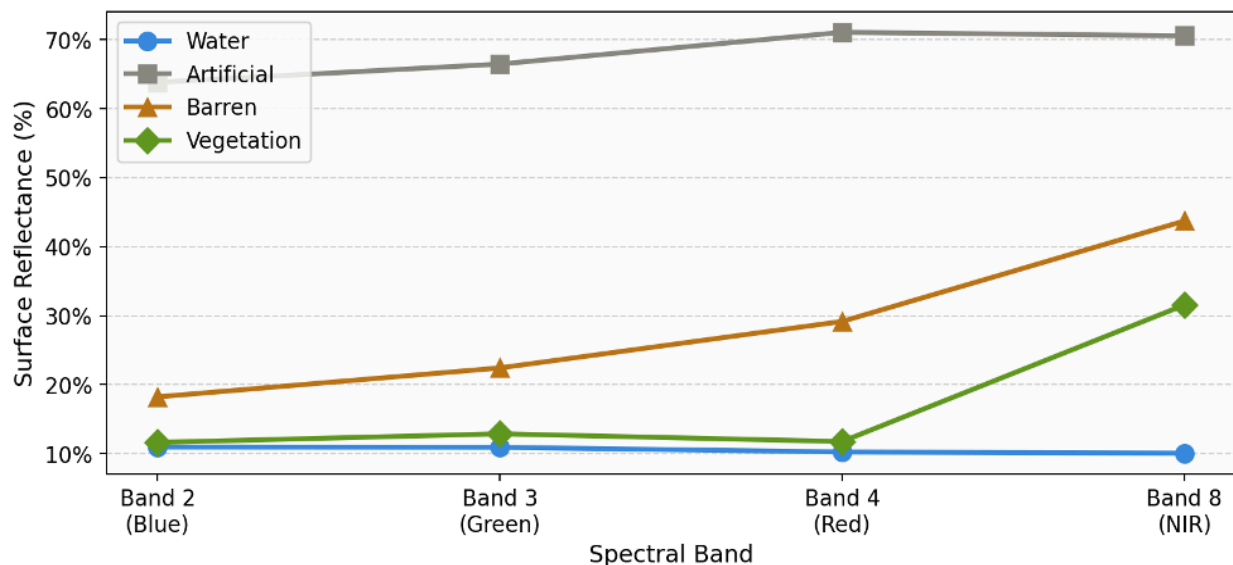


Figure 1. Observed Surfaces across Bands 2, 3, 4, and 8 (Blue, Green, Red, NIR). Water absorbs nearly all NIR energy. Artificial Surfaces reflect strongly across all bands. Vegetation has a sharp increase in NIR. Barren Land increases gradually across all bands.

Methodology

Three classifiers ML, SVM, and RT were applied to both imagery dates using training data developed for each land cover class. Post-classification change detection used the ArcGIS combine tool to overlay the before and after classified raster pixels to quantify class transitions. Accuracy was assessed independently using stratified random ground truth points and evaluated through confusion matrices producing overall accuracy and kappa coefficients for each classifier.

Analysis

All three classifiers achieved Kappa coefficients between 0.863 and 0.944 before the storm, indicating very good to excellent agreement with ground truth data. After Helene, classifier performance diverged. ML declined, with the overall accuracy dropping from 97% to 93% (Kappa from 0.944 to 0.841). SVM improved from 95% to 97% (Kappa

0.885 to 0.967) and RT improved from 94% to 96% (Kappa 0.863 to 0.914). Table 1 and Figure 2 illustrate this divergence

Classifier	Before OA	Before Kappa	After OA	After Kappa
Maximum Likelihood	97.67%	0.944	93.17%	0.841
Support Vector Machine	95.67%	0.885	97.50%	0.967
Random Trees	94.33%	0.863	96.17%	0.914

Table 1. Overall accuracy and Kappa Coefficients. Before and After Hurricane Helene.

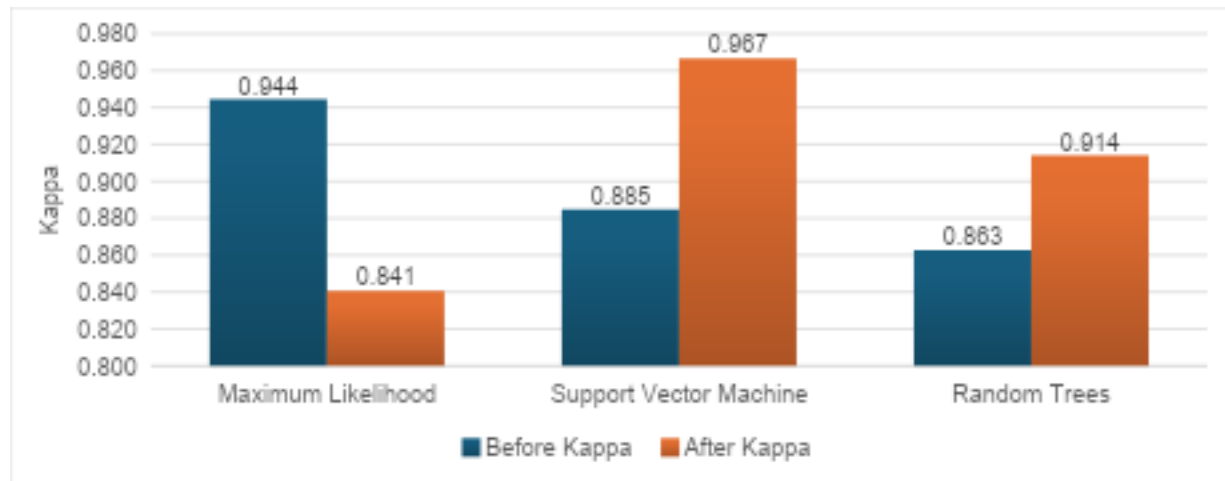


Figure 2. Kappa Coefficient Before and After Hurricane Helene. ML declined post storm while SVM and RT improved, with SVM having the highest post-storm Kappa of 0.967.

Change Detection

Water was the most consistently detected class before the storm due to water's distinctive spectral profile in the NIR imagery. Post-storm, ML detected a 9% point increase in Water (302% relative), while SVM and RT detected minimal changes, suggesting ML misclassified soil and debris as water. Artificial surfaces decreased across SVM and RT (approx. 1.7% points, representing a 68-81% relative loss), consistent with infrastructure damage along HWY-40 and the French Broad River corridor. Vegetation declined in both ML (-9.14% points, -35% relative) and RT (-6.51% points, -9% relative). Barren Land increased most prominently in RT (8.59% points, 44% relative). Table 2 summarizes all findings.

Table 2. Net Scene Change- Percentage Points and Relative Change by Classifier.

Class	ML (pts)	SVM (pts)	RT (pts)	ML Relative	SVM Relative	RT Relative
Water	+8.29	-0.17	-0.37	+302%	-6.6%	-12.8%
Artificial	+0.40	-1.76	-1.71	+0.56%	-80.7%	-68.0%
Vegetation	-9.14	+0.52	-6.51	-35.0%	+0.7%	-8.7%
Barren	+0.45	+1.41	+8.59	+547%	+8.4%	+44.2%

Confidence

High confidence in the classifier performance ranking based on Kappa coefficients above 0.84 across all six assessments and consistent agreement between SVM and RT on key findings. Moderate confidence in individual class changes magnitudes due to single date imagery and potential annual vegetation variability between the two October acquisition dates.

Bias

- Training data was labeled by one analyst, introduced potential for subjective class interpretations.
- Ground truth points were collected and verified by one analyst without independent validation.

Impact

SVM's post storm makes it the recommended classifier for flood damage mapping in vegetated mountain environments. The artificial surface loss confirmed by SVM and RT provides evidence of infrastructure loss to inform recover prioritization along the French Broad River corridor and HWY-40.

Outlook

No single classifier captured the full scope of the landscape transformation. ML most effectively detected Water inundation, RT captured Barren Land expansion from the debris and sediment, and SVM provided the most accurate overall post-storm

classification. Planners and emergency managers should consider applying multiple classifiers in combination to assess disasters. Future research should evaluate classifier performance across multiple post-storm acquisition dates to assess recovery patterns along affected river corridors.

Acknowledgements

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- United States Geospatial Intelligence Foundation (USGIF). Geospatial Intelligence Essential Body of Knowledge (EBK) 3.0. 2024.

Sources

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