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Habitat and Land Cover Change Detection in Alpine Protected Areas

A Comparison of AI Architectures

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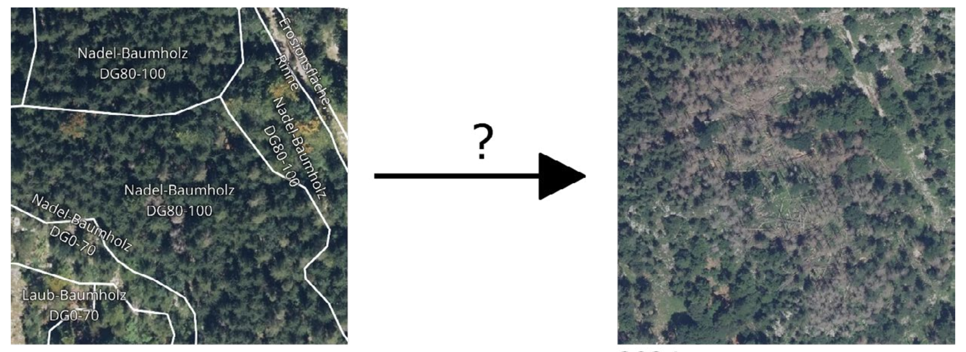
1 Introduction

Problem: Alpine ecosystems warm **2× faster** than the global average, yet habitat monitoring still relies on slow, costly manual mapping.

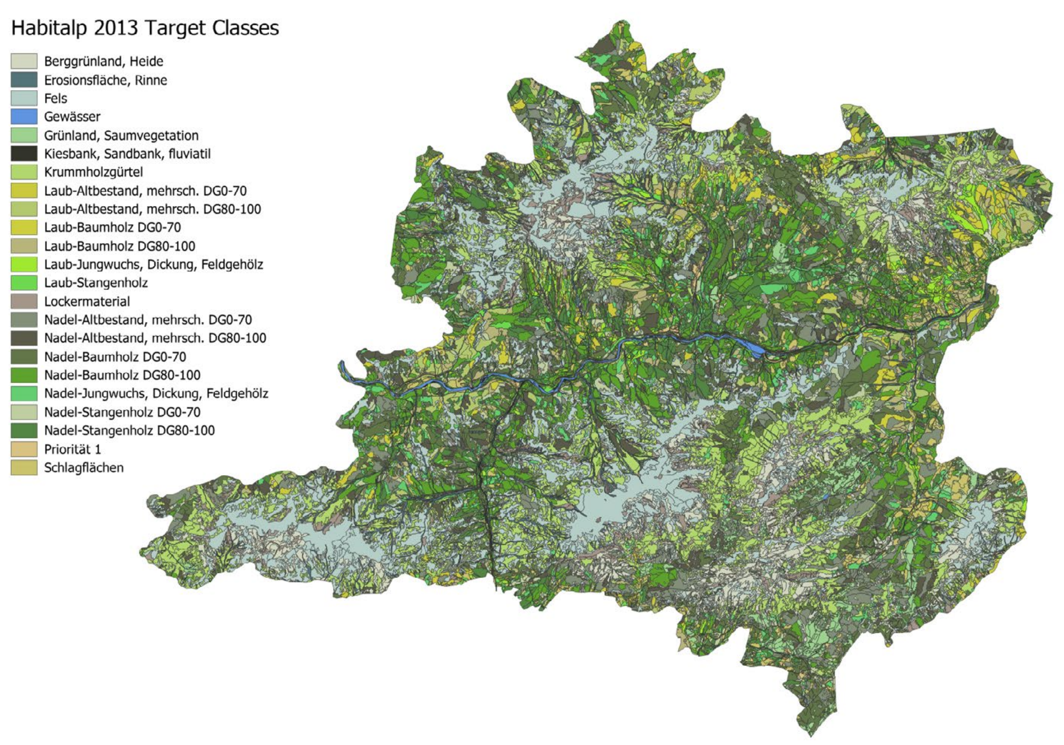


Can AI close the gap? We systematically compare two deep learning paradigms for automated change detection on a unique 17-year alpine dataset.

2 Data & Study Area

Gesäuse National Park, Styria, Austria — Natura 2000 site, eLTER network

- 20 cm RGB + CIR aerial orthophotos (2003–2022)
- Airborne LiDAR, 1 m (2010/11, 2020)
- HabitAlp dataset: 60+ years of mapping → **23 habitat classes**
- **4,480 documented change polygons** over 15.3 km²



3 Methods

All models fine-tuned for semantic segmentation on the 2013 HabitAlp dataset (HuggingFace: JR-DIGITAL/habitalp2.0)

Then applied to 2020 imagery for cross-temporal evaluation.

Input:

- 20 cm RGB + CIR
- LiDAR-derived layers (nDSM, slope, aspect).

Evaluation:

- 70/15/15 spatial train/val/test split
- Overall Accuracy (OA) · Macro IoU · Macro F1
- in-domain (2003–2013) + cross-temporal (2013–2020)

Model	Type	Architecture	Pre-training Data	Size (Params)
Clay v1.5	GFM	ViT (MAE + DINOv2)	Sentinel-1/2, Landsat, NAIP, MODIS	**632M**
Prithvi-EO-2.0	GFM	3D ViT (MAE)	NASA HLS (Landsat 8 + Sentinel-2)	**600M**
Terramind	GFM	Dual-scale Transformer	TerraMesh (Multimodal spatiotemporal)	**500M**
DOFA	GFM	ViT (Dynamic Adapter)	Multi-sensor (Sentinel, NAIP, etc.)	**300M**
Clay v1.0	GFM	ViT	Sentinel-1/2, Landsat, Aerial	**110M**
U-Net	CNN	Encoder-Decoder	ImageNet	**31M**

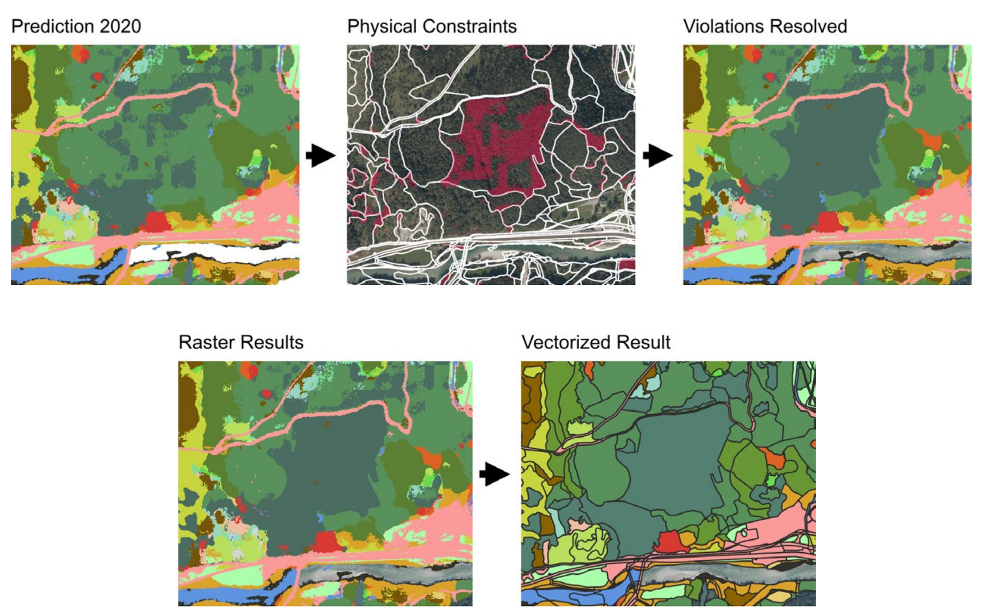
Post-Processing

Object-based post-processing **and physical constraints** eliminate **ecologically impossible habitat transitions** from raw model outputs.

6 thematic filters applied, e.g.:

- Rock → Grassland_ physically impossible (0.4% of area)
- Forest → younger age class: requires recorded disturbance (8.8% of area)

~11% of predicted change area filtered, producing maps directly usable for park management. An example of the post-processing workflow is visualized below:



4 Results

Model Comparison

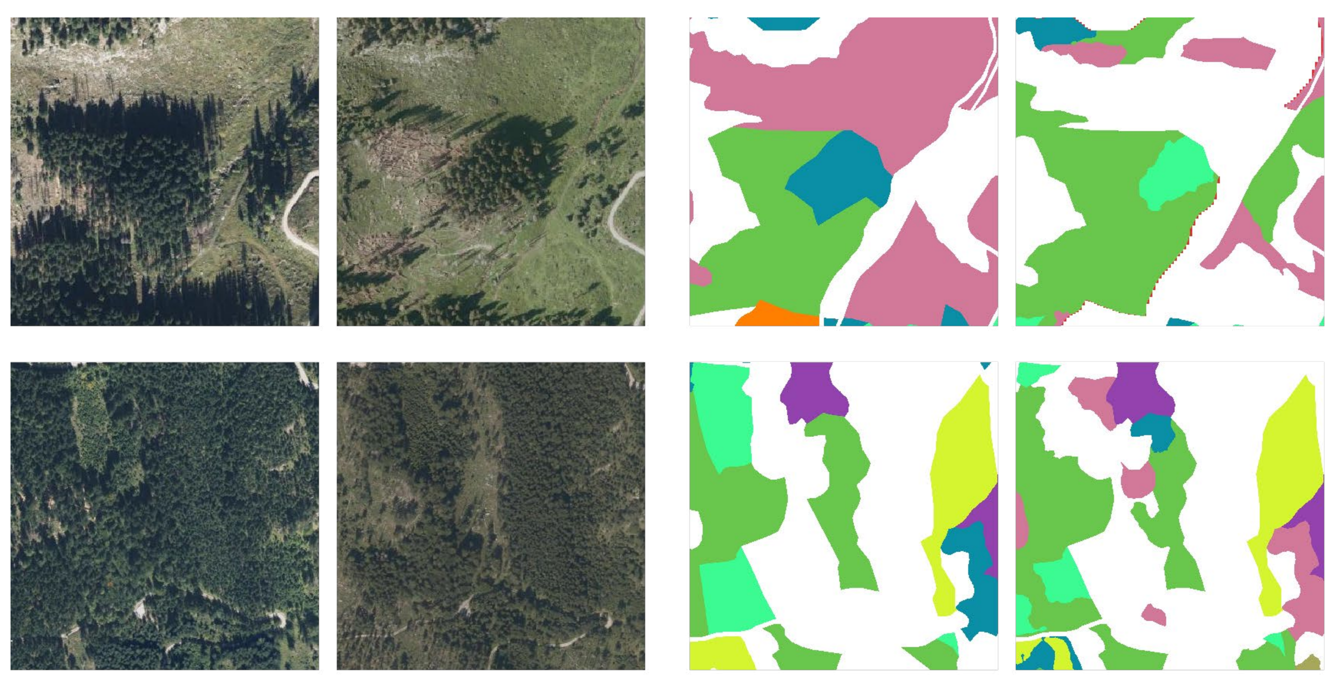
Semantic Classification OA
Baseline: RGB+CIR, in-domain (2003–2013)

Model	*Type*	*OA*	*mIoU*
Clay v1.0	**GFM**	**50%**	**0.32**
Prithvi-EO-2.0	GFM	48%	0.30
U-Net	CNN	48%	0.31
Clay v1.5	GFM	47%	0.29
Terramind	GFM	47%	0.29
DOFA	GFM	45%	0.27

Ablation Study: Multiclass Change Detection

Multiclass Change OA (2013→2020)
Baseline: RGB+CIR (2013→2020)

Condition	Clay v1.0	Terramind	U-Net
Base (RGB+CIR)	**41%**	39%	37%
+ LiDAR	**47%**	43%	41%
+ Post-processing	**50%**	49%	44%



RGB (2013) RGB (2020) Ground Truth (2013-2020) Post-classification: Clay v1.0

Mature forest with canopy cover loss
Old-growth forest with canopy cover loss
Forest growth stage setback
Forest development stage progression
Forest canopy cover gain
Early forest establishment (regeneration/regrowth)
Clearcut
Other Transition
No Change

5 Key Findings & Outlook

Key Findings

GFMs outperform U-Net on multiclass change detection

+4 to +6 % OA across all conditions; advantage grows with LiDAR

Binary change: models comparable

GFM advantage is specific to what changed, not just that something changed

LiDAR is the biggest single lever

Multiclass OA: 41% → 47% for best GFM (+6 %)

Post-processing makes outputs actionable

+9% OA on classification; eliminates ecologically impossible transitions

Outlook

- Expand to additional national parks
- BioDivAI extends habitat mapping to biodiversity impact prediction under land use change scenarios
- Investigate LiDAR × post-processing interaction for targeted PP design

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Poster title

Subtitle

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