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Optimized UAV-LiDAR Workflows for Fine-Scale Stream Network Mapping in Low-Gradient Wetlands

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INTRODUCTION

Wetlands provide critical ecosystem services, but human activities like channelization have degraded many systems worldwide.

Kushiro Wetland, a Ramsar site in Japan, where channelization has disrupted hydrologic connectivity and threatened biodiversity.

To address these impacts, a restoration project was undertaken between 2006 and 2011 to re-establish the river's original meandering course. For such restoration efforts, understanding the original or target hydrological regime is critical.

www.triptojapan.com/places/kushiro-marshland/egC3ass6TIKxK2ZF-wIUyQ

Research Objectives

1 SYSTEMATIC EVALUATION

- Test 48 UAV-LiDAR processing workflows
- Comprehensive pairwise comparison (1,128 combina

2 WETLAND-SPECIFIC OPTIMIZATION

- Identify optimal methods for low-gradient terrain
- Component-wise performance assessment

3 DUAL VALIDATION APPROACH

- Statistical inter-method consensus
- Independent satellite imagery validation
- Reveal consensus-accuracy gap

4 OPERATIONAL RECOMMENDATIONS

- Evidence-based workflow selection
- Support Kushiro Wetland Restoration Project
- Framework applicable globally

METHOD

WORKFLOW COMPONENT COMBINATIONS

GROUND FILTERING (3 methods)

- **PMF** (Progressive Morphological Filter)
- **CSF** (Cloth Simulation Filter)
- **MCC** (Multiscale Curvature Classification)

INTERPOLATION (4 methods)

- **IDW** (Inverse Distance Weighting)
- **MBA** (Multilevel B-spline Approximation)
- **TIN** (Triangulated Irregular Network)
- **KRG** (Kriging)

SINK-FILLING (2 methods)

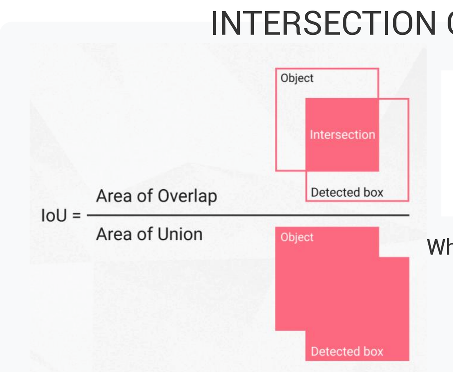
- **Wang & Liu** (2006) **Planchon & Darboux** (2001)

FLOW DIRECTION (2 methods)

- **D8** (8-direction) **D-infinity** (Multiple flow)

EVALUATION METRIC BOX

INTERSECTION OVER UNION (IoU)



$$\mathrm{IoU} = \frac{TP}{TP + FP + FN}$$

Where:

- TP = Both methods detect channel
- FP = False positive (over-extraction)
- FN = False negative (under-extraction)

Range: 0 (no overlap) to 1 (perfect match)

✓ Penalizes both over- and under-extraction
✓ Robust for imbalanced datasets

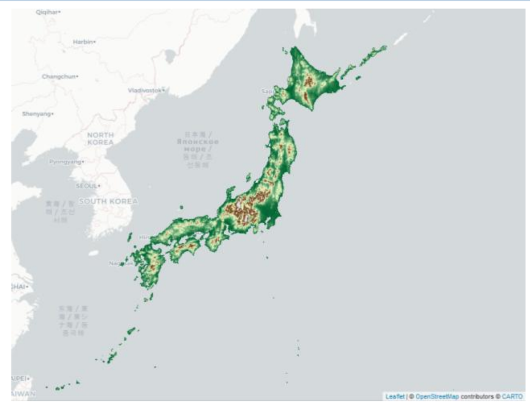
3 × 4 × 2 × 2 = **48** WORKFLOWS

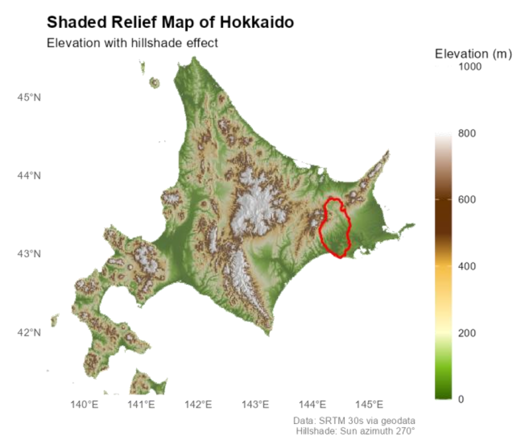
C(48,2) = **1,128** PAIRWISE COMPARISONS

48 Workflows → 1,128 Comparisons → Statistical Analysis → Satellite Validation → Recommendations

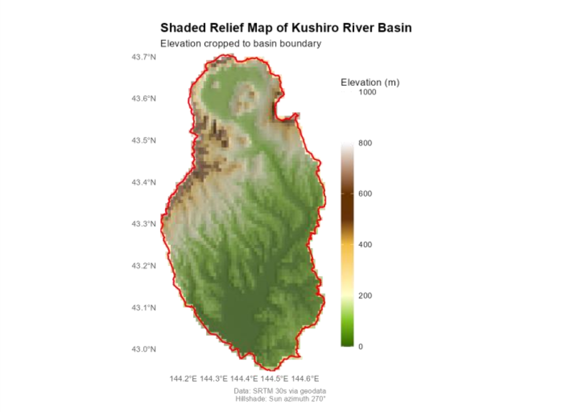
STUDY AREA & DATA ACQUISITION

Japan & Hokkaido



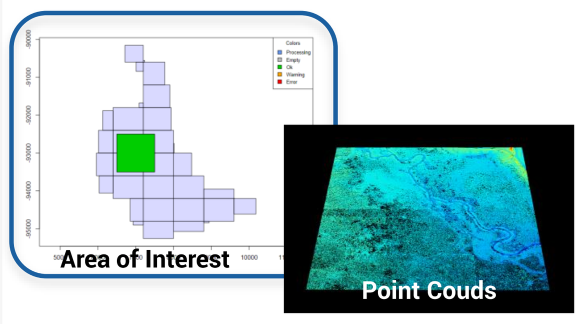


Kushiro Wetland



www.triptojapan.com/places/kushiro-marshland/egC3ass6TIKxK2ZF-wIUyQ

Study Area Detail



DATASET SPECIFICATIONS

Area: 0.91 km²	Point Density: 4.76 pts/m²
Platform: DJI Matrice M300 RTK	Sensor: DJI Zenmuse L1 LiDAR
Acquisition: November 2017	Validation: Sentinel-2 (10m)
Relief: < 1m total range	Vegetation: Mixed reed-sedge-alder

RESULTS & DISCUSSION

⚠ Critical Discovery: Statistical Consensus ≠ Actual Accuracy

Statistical Champion

PMF-TIN-Planchon-Dinf

Rank:	1st of 47
Median IoU:	1.0000 (perfect)
SD:	0.0000 (no variability)
Inter-method consensus:	HIGHEST

Satellite Validation: MODERATE
"Agreed with other methods but not with reality"

Validated Champion

CSF-MBA-Planchon-D8

Rank:	37th of 47
Median IoU:	0.8460
SD:	0.0527
Inter-method consensus:	High

Satellite Validation: EXCELLENT
"Matched observable channel features"

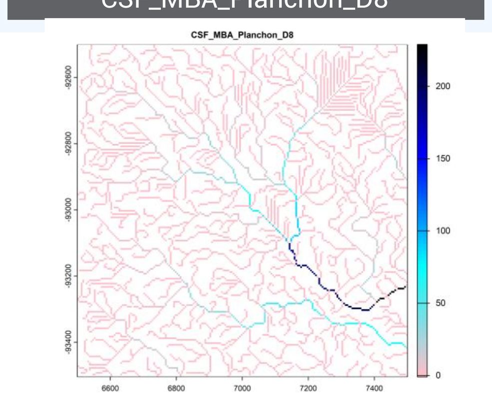
Comparison Table

Criterion	Statistical Best	Validated Best
Pairwise Rank	1/47	37/47
Median IoU	**1.0000**	**0.8460**
Sentinel-2 Match	Moderate	⭐ **Excellent**
Recommendation	⚠ Conditional	✅ YES

Satellite Image Validation

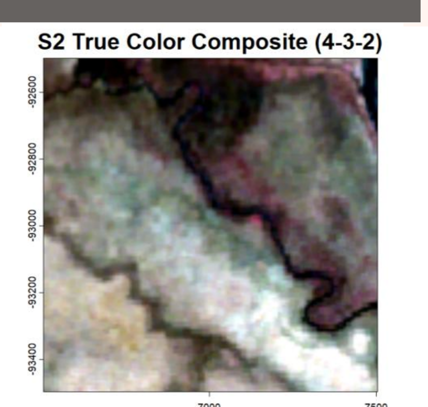
LiDAR-Derived Channel Network

Validated Workflow Output: CSF_MBA_Planchon_D8



Satellite Image Reference

S2 True Color Composite (4-3-2)



VALIDATION FINDINGS

Visual comparison with Sentinel-2 true color composite imagery indicates this workflow provides the most accurate representation of actual channel locations, despite not ranking highest in pairwise statistical comparison.

IMPLICATION **High inter-method agreement ≠ absolute accuracy**
Independent validation is essential

CONCLUSION

Statistical consensus does not guarantee accuracy—workflows with perfect agreement showed only moderate correspondence with actual channels. Context-specific methods are essential: our validated CSF-MBA-Planchon-D8 workflow outperformed conventional approaches in low-relief wetlands. Independent validation and wetland-optimized algorithms are critical for accurate channel extraction.

FUTURE WORK / REFERENCES

Expand validation across diverse wetland types globally, integrate multi-temporal LiDAR for seasonal dynamics, incorporate machine learning optimization, and validate with field-based hydrological measurements.

Zhang et al. (2016) *Remote Sensing* 8(6):501;
Evans & Hudak (2007) *PE&RS* 73(1):87-102;
Lindsay (2016) *Computers & Geosciences* 95:75-84.

Conference paper:
DOI: https://sciforum.net/paper/view/26367

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