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MDPI

Spectral and Spatial Super-Resolution of ALSAT-2B Imagery Using a SwinUNet Generative Model for Enhanced Forest Monitoring

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INTRODUCTION & AIM

Algeria's ALSAT satellite provides key environmental data, but its technical limitations hinder advanced forest monitoring. With only four spectral bands (RGB-NIR), it cannot detect early signs of drought or disease, and its 10m resolution obscures fine-scale damage. This research leverages AI to enhance existing ALSAT imagery, providing a cost-effective way to generate richer, more actionable data for protecting Algeria's forests.

(a) Multispectral 10 m (b) Panchromatic 2.5 m

Figure 1: Visual Comparison of Multispectral and Panchromatic Imagery from ALSAT-2B

METHOD

Phase 1
Spectral Super-Resolution

1. Data Preparation

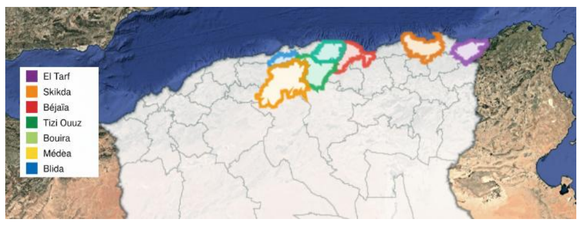


Figure 2: Dataset Coverage: Northern Algeria Forest Regions 18 co-registered scene pairs | BOA-corrected | Sub-pixel aligned

2. SwinUNet Architecture

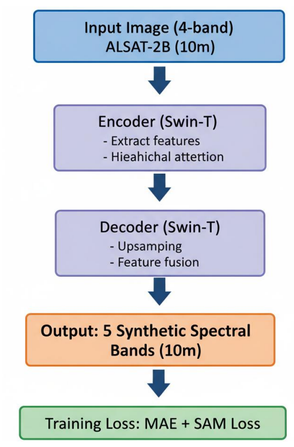


Figure 3: SwinUnet architecture

Phase 2
Spatial Super-Resolution

1. Gram-Schmidt Pansharpening

- Upsample 9-band stack to 2.5m
- GS orthogonal transformation
- Substitute first component with PAN band
- Inverse GS transform

2. Adaptive Intensity Matching

- Dynamic percentile normalization (2-98% or 5-95%)
- Maximizes correlation between PAN and synthetic intensity
- Scene-specific optimization

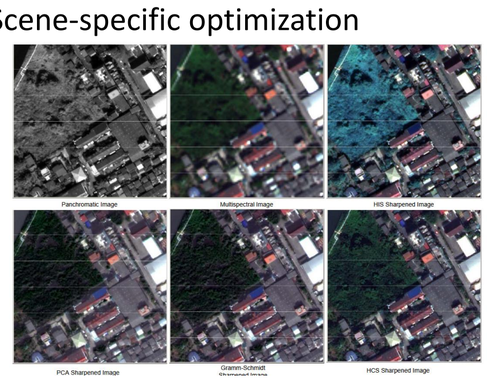


Figure 4 : Visual comparison of pansharpening algorithms. Adapted from Padwick et al., 2010

Phase 03
Forest Classification Validation

Experimental Scenarios

Baseline: 4 bands + NDVI (10m)
Spectrally Enriched: 9 bands + NDVI (10m)
Fully Enhanced: 9 bands + NDVI (2.5m)

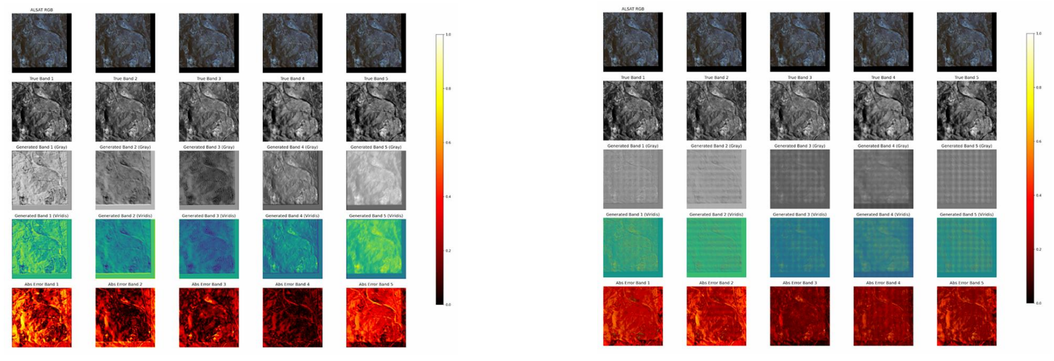
Classification Protocol

Ground truth: ESA WorldCover 2021 (binary forest mask)
Classifier: Random Forest
Training: 20% stratified pixel sample
Metrics: Overall Acc., F1-Score

RESULTS & DISCUSSION

Table 1: Spectral Super-Resolution Model Comparison Performance

Model	Avg PSNR (dB)	Avg SAM (rad)	Avg SSIM
Pix2Pix U-Net	6.63	1.537	0.007
SSRGAN	18.64	0.163	0.52
SpectralResNet	20.72	0.154	0.56
Attention ResUNet	20.37	0.122	0.59
SwinUNet	**24.34**	**0.107**	**0.63**



(a) SwinUNet (b) Pix2Pix U-Net

Figure 5: Qualitative Comparison of Synthesis Models

Table 2: Pansharpening Quality Assessment

Region	Optimal Normalization	Correla tion	SAM (rad)	ERGAS	Q-Index
Blida	2-98%	0.8226	0.105	5.65	0.9339
Tizi-Ouzou	5-95%	0.7730	0.134	7.18	0.9025
Béjaïa	5-95%	0.7135	0.160	8.36	0.8702

(a) Before (b) After

Figure 6: Before and After Enhancing Spatial Detail of ALSAT-2B Imagery

Pansharpening Success

- All regions achieve SAM < 0.16 rad
- Q-index > 0.87 confirms structural preservation
- Adaptive normalization ensures scene-specific optimization

Table 2: Forest Classification Performance

Scenario	Input Data	Accuracy (%)	F1 Score (%)	Gain (pts)
Baseline	4 bands (10m)	64.58	60.28	---
Spectrally Enriched	9 bands (10m)	74.44	70.08	+9.8
Fully Enhanced	**9 bands (2.5m)**	**77.75**	**74.03**	**+13.75**

CONCLUSION

Spectral Enrichment
- 5 Bands Synthesized
- PSNR 24,34 dB

Spatial Enhancement
- 2.5m Resolution Achieved

Classification Gain
- +13.75 points in F1 Score

Performance Gain
- 43% in false positives
- 16% in false negatives

FUTURE WORK / REFERENCES

1. **Diffusion Models:** Explore stochastic approaches for better spectral detail.
2. **Physics-Aware Losses:** Add radiative constraints for realism.
3. **Rich Data:** Use diverse seasons and times to enhance generalization.

1. Nie, Z., Chen, L., Jeon, S., & Yang, X. (2022). Spectral-Spatial Interaction Network for Multispectral Image and Panchromatic Image Fusion. Remote Sensing, 14(16), 4100.
2. Zhang, K., Sumbul, G., & Demir, B. (2020). An Approach To Super-Resolution Of Sentinel-2 Images Based On Generative Adversarial Networks. In M2GARSS 2020.