OPEN UNESCO INVENTORY → CROSS-REGION SATELLITE TRANSFER

Training on 111 public Wadi Dawkah frankincense trees to map remote Boswellia sacra habitats from orbit.

Operal AG ingested the open public tree inventory published for the UNESCO World Heritage site at Wadi Dawkah (wadidawkah.com), resolved GPS pin offsets and global LiDAR blind spots on 60 cm WorldView-3 imagery, and transferred the calibrated ensemble 41 km south-west across Dhofar to map unverified Boswellia sacra candidates at Jabal al-Qamar (17°04'42.5"N 53°48'05.0"E, 1'133 m).

111
Open-inventory Wadi Dawkah trees (30 Small, 47 Large, 34 Giant) on 0.59 m WV03 RGB

0.985
5-fold CV ROC-AUC after EM snapping (up from 0.309; Small recall 96.7%)

0 / 111
Confirmed desert crowns ≥ 1 m in global 1 m CHM (100% sparse-crown zero-inflation)

+25 / −51
Jabal al-Qamar open crowns uplifted vs cliff/rock shadows filtered (88 total)

01 Open-inventory learning & domain adaptation.

Both Dhofar landscapes share dry-January ~0.59 m/px WorldView-3 RGB geometry (21.01.2026 at Wadi Dawkah; 06.01.2025 at Jabal al-Qamar). Three mechanisms govern cross-region generalisation:

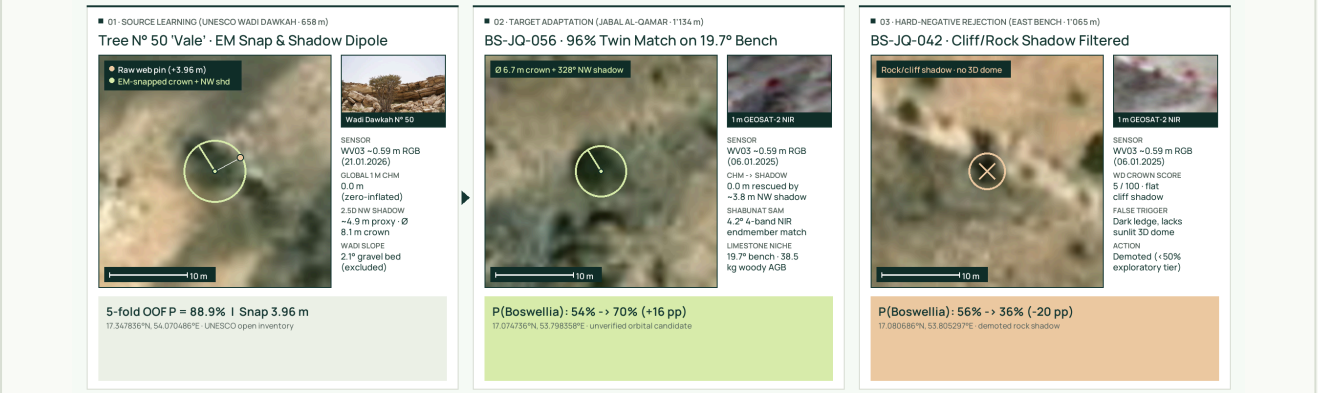
- **EM web-pin snapping (r ≤ 4.2 m):** Public coordinates on wadidawkah.com carry a 3.44 m median offset onto bare gravel. Two-pass Expectation-Maximisation aligns crowns alongside 332 Positive-Unlabelled hard negatives (cliff shadows, dark boulders, stone walls, gravel beds).
- **2.5D solar-shadow dipole replaces CHM penalty:** Meta/WRI 1 m Canopy Height reports 0 m on all 111 Wadi Dawkah trees. Operal replaces the flat CHM = 0 m penalty with a 328° NW cast-shadow + sunlit SE dome dipole while retaining CHM ≥ 1 m (16 trees) as positive confirmation.
- **Covariate-shift topographic guardrail:** Wadi Dawkah (658 m) hosts trees in flat 1°–5° gravel beds, whereas monsoon-margin Jabal al-Qamar (1'133 m) floods wadi channels (Acacia/Tamarix) and restricts Boswellia sacra to 7.5°–36° limestone benches. Slope is excluded from source training and paired with 4-band NIR SAM calibrated on Shabunat / Kadat 1 (2.15 km N; Alamri & AL-Shanfari 2025).

02 Four-iteration quantitative progression.

ITER	PIPELINE STAGE	ROC-AUC	PR-AUC	OUTCOME
00	Raw public pins (unsnapped baseline)	0.309	0.210	53.3% Small rec.
01	EM Pass 1 + L2 invariant logistic	0.862	0.705	2.36 m med. snap
02	**EM Pass 2 + Logistic/HGB ensemble**	**0.985**	**0.957**	**96.7% Small rec.**
03	Jabal al-Qamar 7-sensor fusion	—	—	8 High · 61 Med

Learned domain-invariant feature weights: crown dark contrast (19.2%), NW sun–shadow dipole (18.8%), crown circularity (18.2%), warm bark/foliage R–B chroma (11.1%), 3D mound convexity (7.8%), Landsat thermal coolness (5.9%), and 2.5D shadow height (4.7%).

03 Illustrated worked example — Wadi Dawkah Tree N° 50 'Vale' → Jabal al-Qamar BS-JQ-056.



01 · Learn on N° 50 'Vale' (Wadi Dawkah)
Raw public pin lands 3.96 m ENE on bare gravel. EM Pass 2 snaps to the Ø 8.1 m crown. Despite 1 m CHM = 0.0 m, the 328° NW shadow resolves ~4.9 m height (OOF P = 88.9%); its 2.1° wadi slope is masked out before transfer.

02 · Uplift BS-JQ-056 (96% Twin)
Previously capped at 54% by CHM = 0.0 m. Matched at 96% cosine similarity to 'Vale' (Ø 6.7 m, ~3.8 m shadow proxy) + 4.2° Shabunat NIR SAM + 19.7° limestone bench → uplifted +16 pp to 70% (±14%).

03 · Reject BS-JQ-042 (False Crown)
Dark ledge on East Wadi Bench previously scored 56% from shade contrast alone. Ensemble detects a flat shadow lacking a sunlit 3D crown dome (score 5/100) → demoted −20 pp to 36% (Exploratory).

Provenance & epistemic limits. Open source inventory: UNESCO World Heritage Wadi Dawkah (wadidawkah.com). WorldView-3 layers are rendered RGB JPEGs (~0.59 m/px from 0.31 m source; Esri / Vantor) with no WV03 NIR/SWIR bands or DEM; 4-band NIR derives from 1.0 m GEOSAT-2 (27.12.2022). All 88 Jabal al-Qamar detections carry **status: image-candidate**, **observedAt: null**, and cap ≤ 0.92 pending field GNSS verification.