RETROCHANGE · USE CASE

Disturbance regime in Carpathian beech old-growth forests

Canopy gaps from declassified 1975 KH-9 satellite imagery

HAVEŠOVÁ · POLONINY · SLOVAKIA

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eosc | GRAVITY

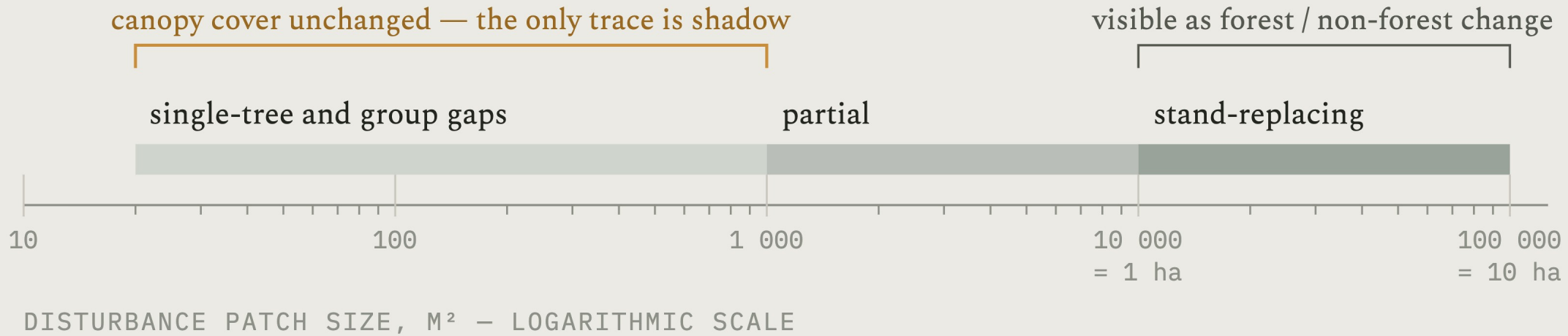
Funded by the European Union

Which disturbance regime shaped this forest?

In beech old-growth the expected answer is **gap dynamics** — a canopy opened a few square metres at a time, by one or a few trees dying *(Drössler & von Lüpke 2005; Kucbel et al. 2010; Feldmann et al. 2018)*.

> Which is exactly the regime that a forest / non-forest map cannot see.





What the definition asks, and what the image can answer

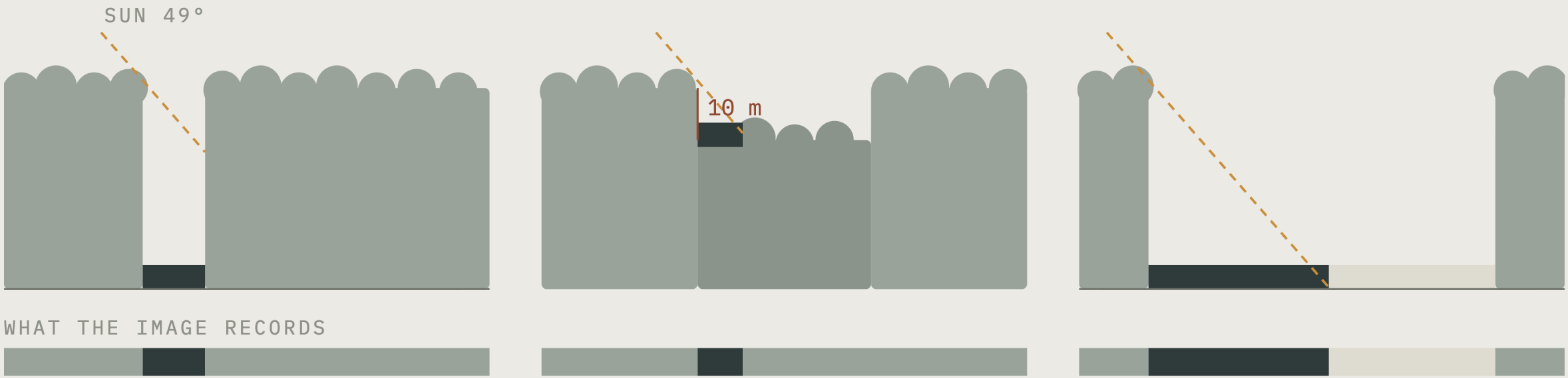
KH-9 Hexagon, 1975. **One panchromatic band at 0.5 m** — no stereo pair, no lidar, no canopy height model.

CRITERION	WHAT THE STANDARD DEFINITION ASKS	THIS IMAGE
MINIMUM AREA	An opening of at least 4–20 m^2, depending on the study.	AVAILABLE
HEIGHT	The opening reaches below a height threshold — 2 m above the ground *(Brokaw 1982)*, or one third to two thirds of top height *(Kucbel et al. 2010; Feldmann et al. 2018)*. The threshold itself is a convention, and it differs between studies.	OUT OF REACH

> Height is out of reach. What is left is brightness — and therefore shadow.

The shadow and the gap are not the same thing

Shade is the only trace the image carries — and it stands for an opening, for a step between crowns, or for part of a gap, without distinguishing them.



A · OPENING TO THE GROUND
12 m wide — dark patch 12 m

B · NO OPENING AT ALL
a crown 10 m lower — dark patch 9 m

C · OPENING 67 M WIDE
half its floor is sunlit — dark patch 35 m

First, take the hillside out

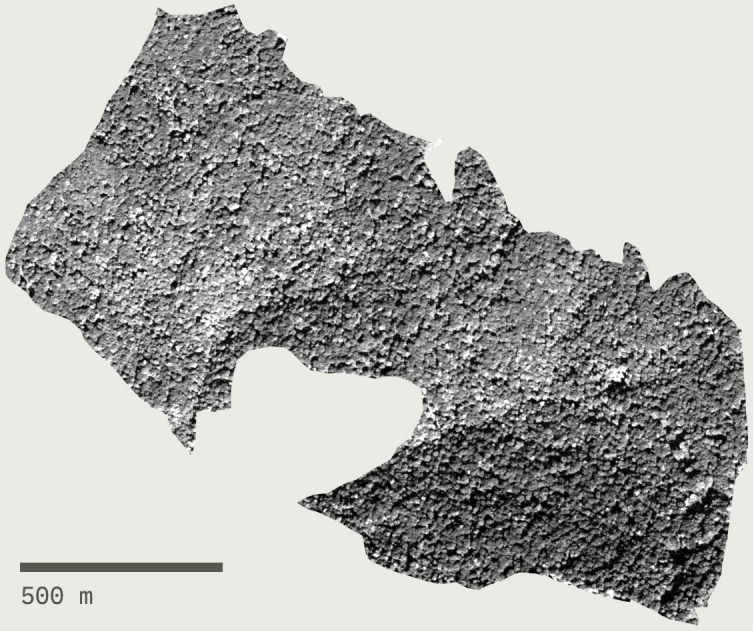
On the shaded slope the whole canopy is darker — **by as much as separates a crown from a gap**.

So each pixel is measured against the typical brightness within 150 m:

$$(DN - median_{150\ m}) \div median^{0.5}$$

From the image alone — no terrain model.

THE IMAGE AS IT COMES



HILLSIDE SHADING REMOVED



N ↑ · Havešová, 144.7 ha

> An opening now looks similar in sun and in shade.

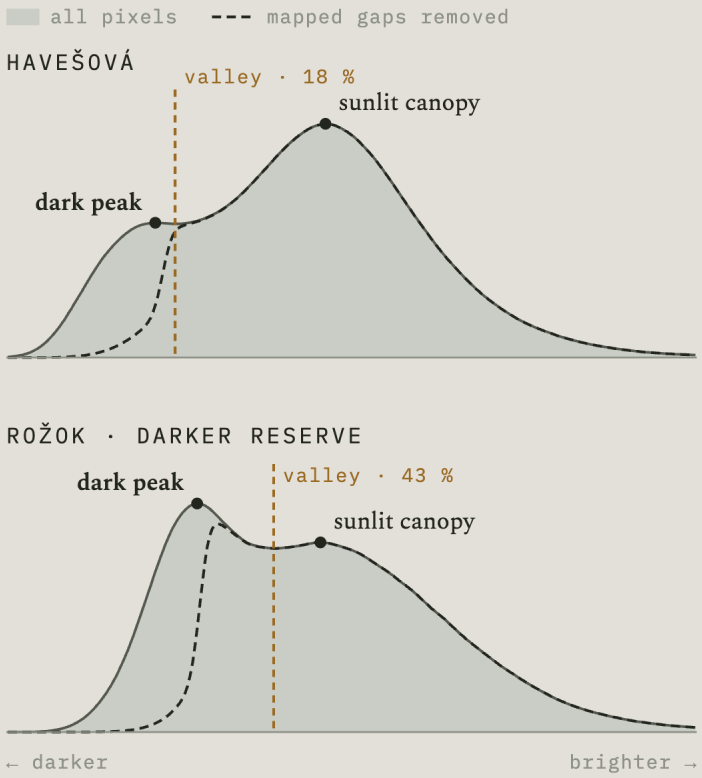
Which shade is a canopy gap?

HISTOGRAM VALLEY

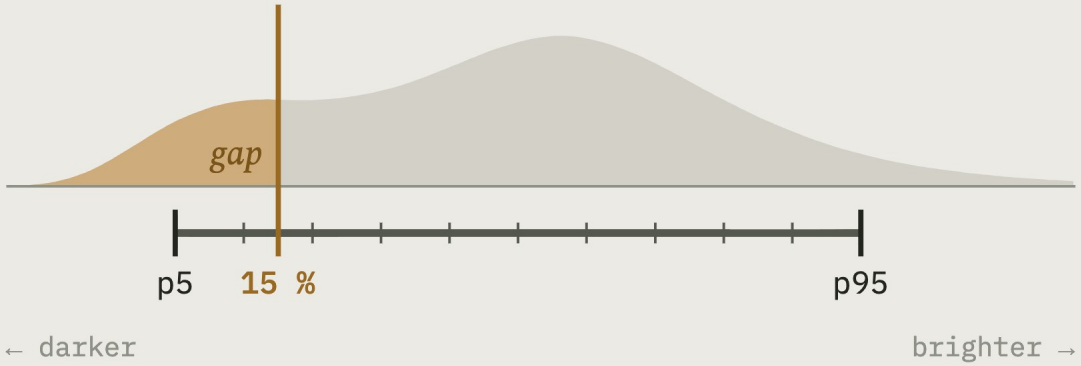
REJECTED

Cut at the low point between the dark and the bright peak. **In Rožok the dark peak is mostly shaded canopy** — the valley would mark 43 % of the reserve as gap, against 18 % in Havešová.

HISTOGRAM VALLEY



A mark on the brightness scale

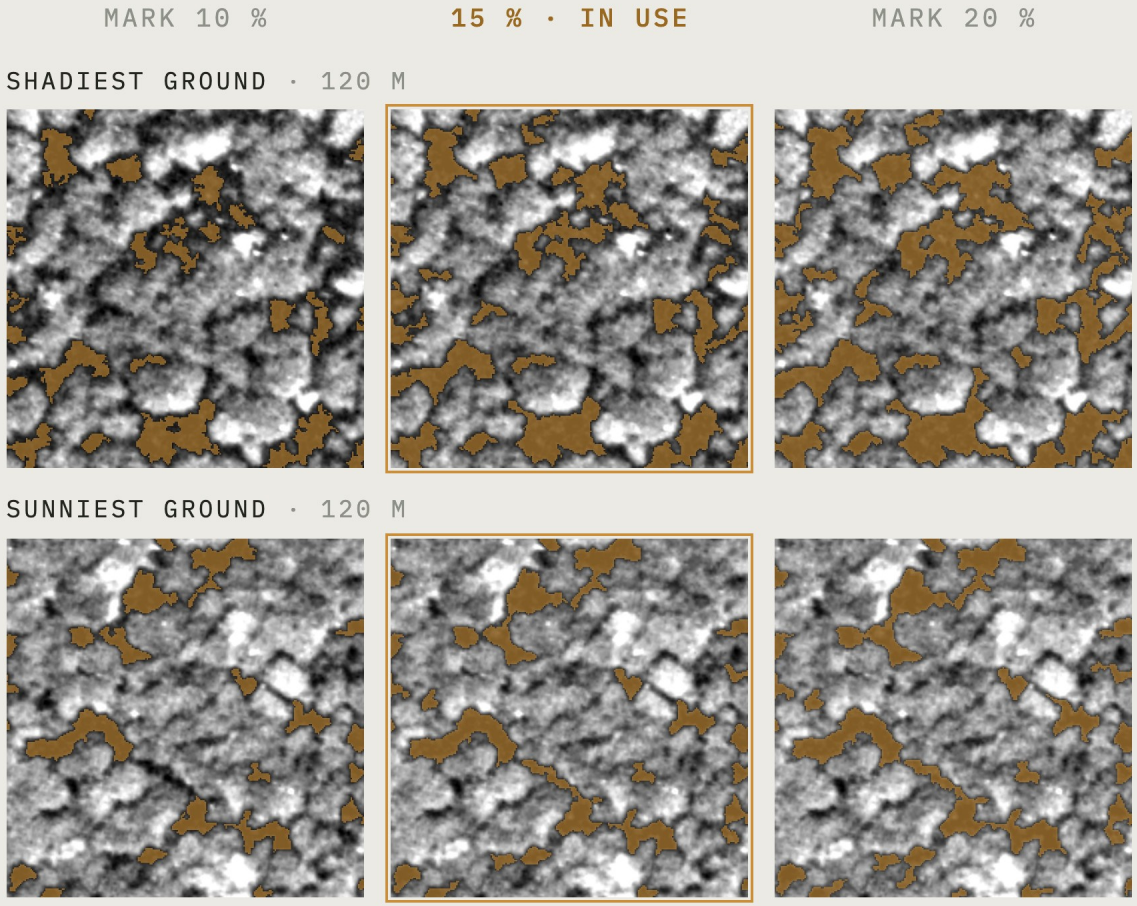



```
cut = p5 + 0.15 × (p95 − p5)
```

> The range is taken from **the image itself**, so it fits each forest.

> The mark is **a place on the scale** — a gappier forest shows more gap.

> **The 15 % is set by eye.**



What we call a canopy gap

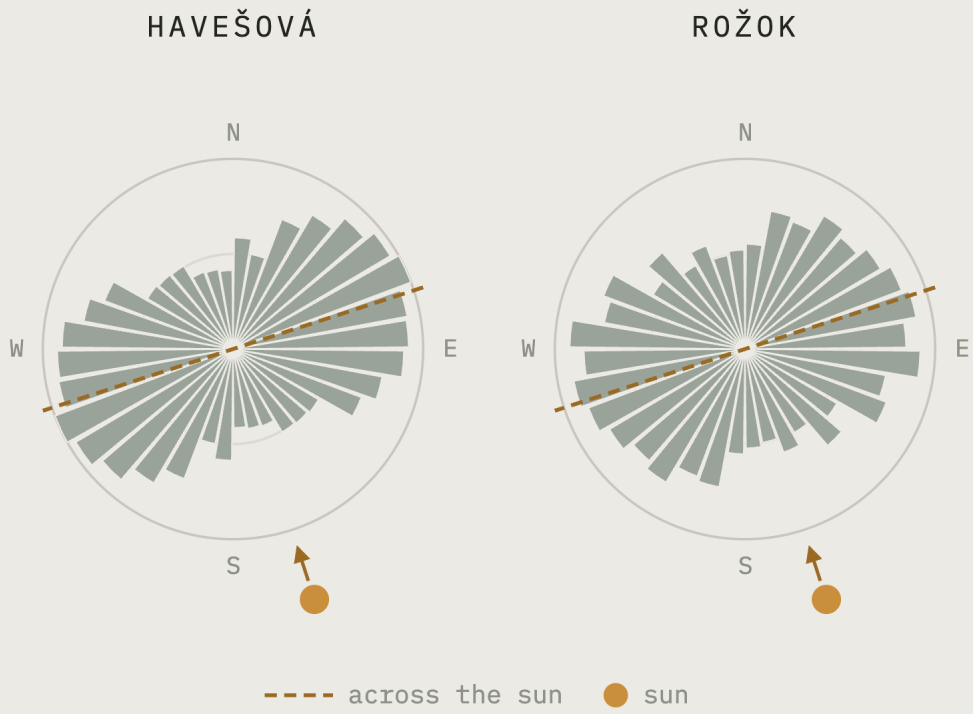
> A patch of **at least 20 m²** that is darker than **the 15 % mark** of its own illumination-corrected brightness scale.

STEP	SETTING	VALUE
ILLUMINATION	Neighbourhood that defines local brightness	150 m, median
	How strongly shade is corrected	α = 0.5
THRESHOLD	Mark on the brightness ruler, whose ends trim the extremes	15 % of p5–p95
PATCH	Holes inside a gap filled up to	8 m²
	Smallest patch counted as a gap	20 m²
CLEANING	Thin shadow filaments removed	< 1 m wide, ≥ 2 m long
HAND EDITS	Gaps can be added or erased by hand	per forest

> To compare forests, keep every setting fixed — change only the image.

A gap, or the trace of one?

1. The dark patches share one direction — **across the sun** — in both reserves.
2. It is **not the terrain** — a terrain model shows no relation.
3. The sun shades a shallow dip only along its sunward edge: the dark patch comes out as **a thin strip lying across the sun**. So shallow dips are mapped as well as true gaps.



> What we map are **canopy depressions** — mostly traces of current or past disturbance, of unknown age.

Canopy gaps (depressions) covered 13.96 % of the reserve

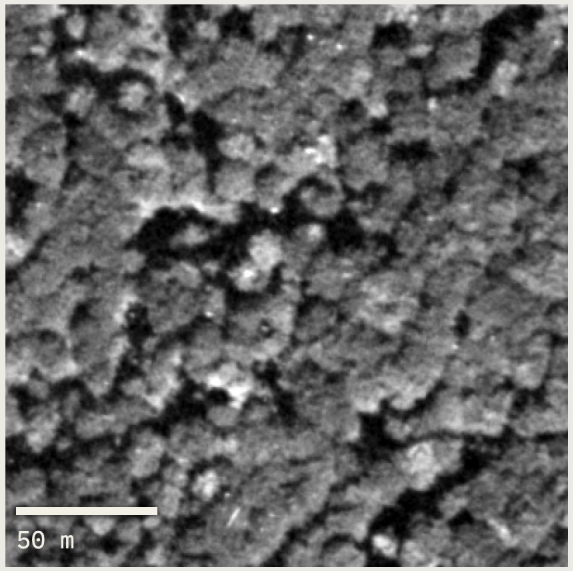
GAPS	1 996
DENSITY	13.8 / ha
FRACTION	13.96 %
AREA	20.2 of 144.7 ha

WHOLE RESERVE

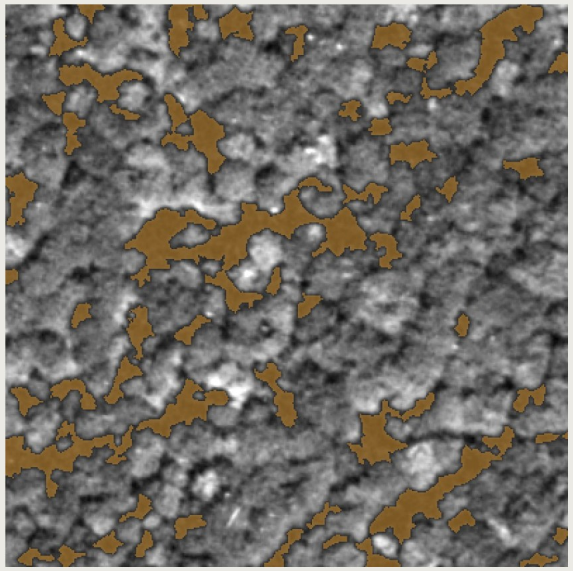


N ↑ · 144.7 ha

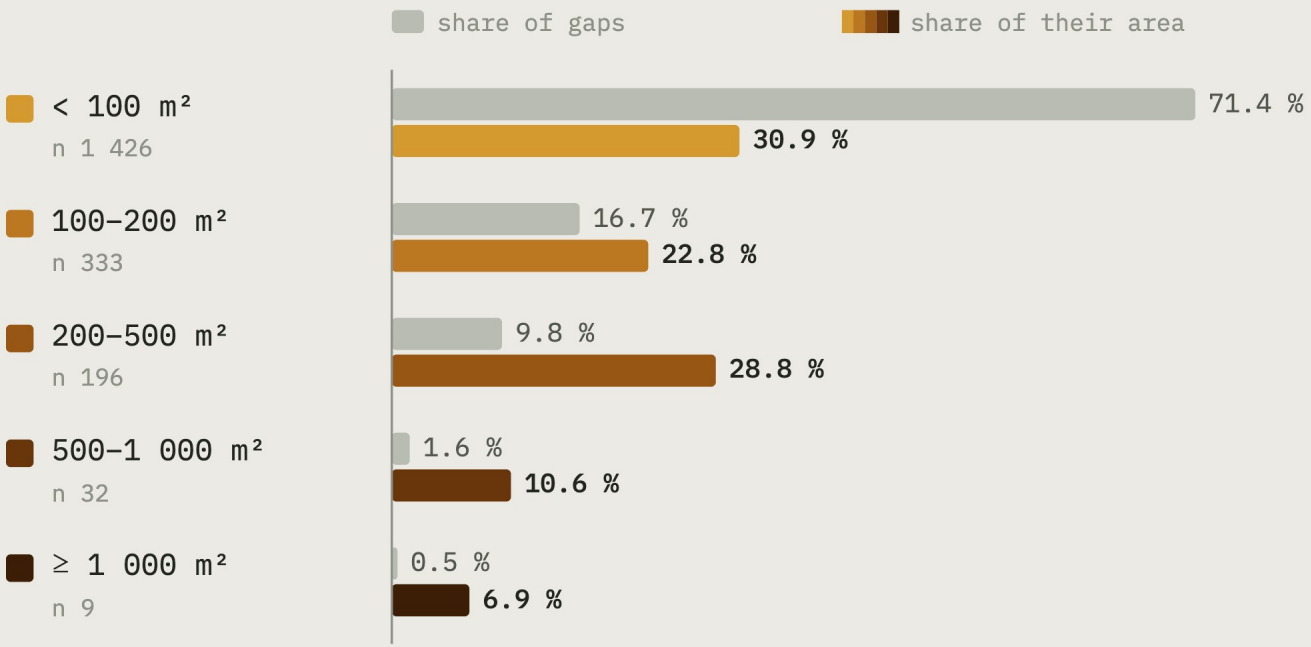
200 M WINDOW



SAME WINDOW



Small gaps dominated the count, larger ones the area



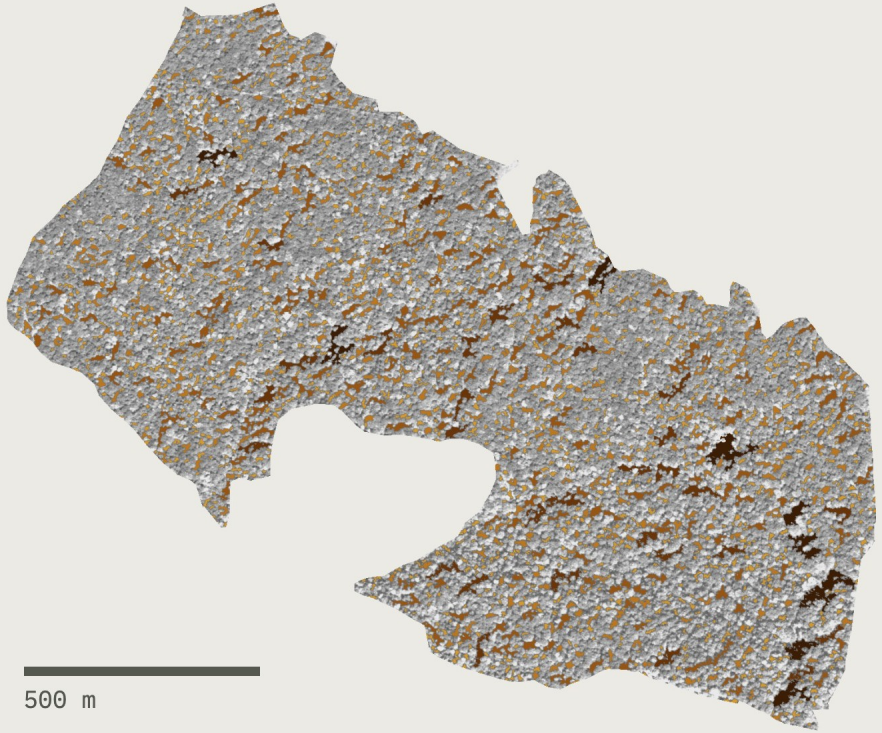
MEDIAN
50.5 m²

HALF THE AREA IN
> 183 m²

LARGEST 5 % HOLD
29 %

LARGEST
0.27 ha

BY SIZE CLASS



N ↑ · colours as in the bars

Valleys and shaded slopes held more gap area

FRACTION, % · WHOLE RESERVE 13.96

	SHADED	MID	SUNNY
VALLEY	18.7	16.5	14.9
MID-SLOPE	14.9	15.2	11.1
RIDGE	12.4	12.5	9.1

DENSITY, PER HA · WHOLE RESERVE 13.8

SHADED	MID	SUNNY
13.4	15.4	15.3
12.0	13.4	14.7
13.0	13.7	13.3

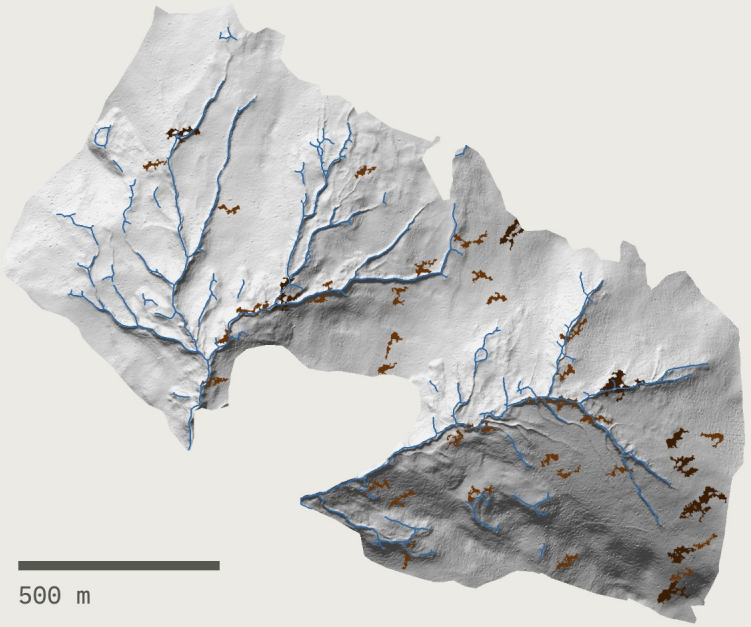
SHARE ≥ 200 M², % · WHOLE RESERVE 11.9

	SHADED	MID	SUNNY
VALLEY	17.9	13.2	11.9
MID-SLOPE	17.1	16.9	5.6
RIDGE	11.0	9.2	4.4

Colour: each cell against the whole reserve.

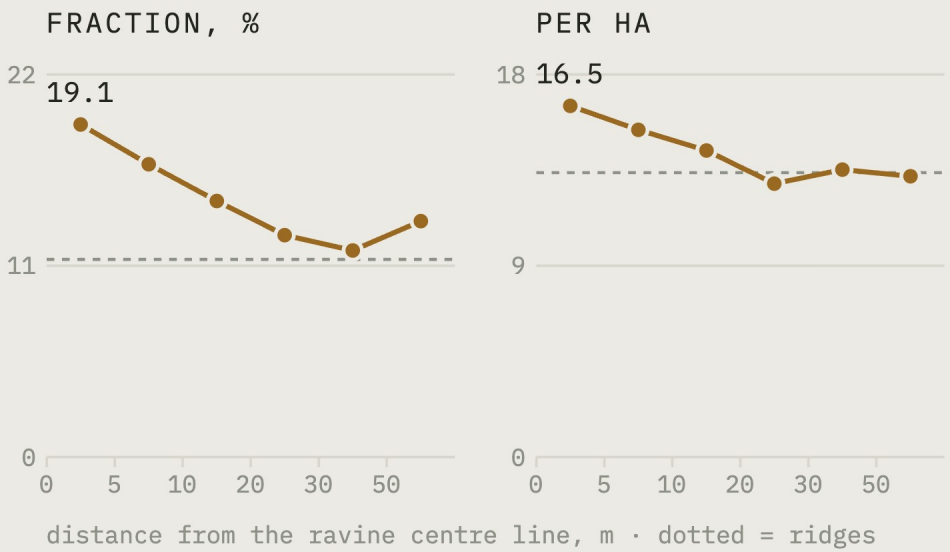
less — about the same — more

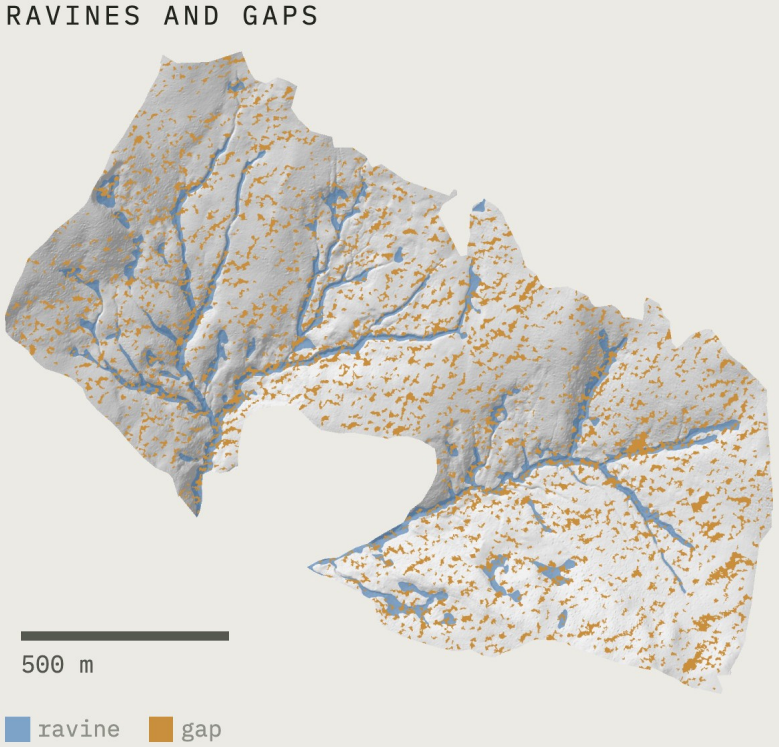
TERRAIN SHADING



> Over a valley the canopy surface follows the concave ground — part of this may be terrain, not disturbance.

Gaps peak along the ravines

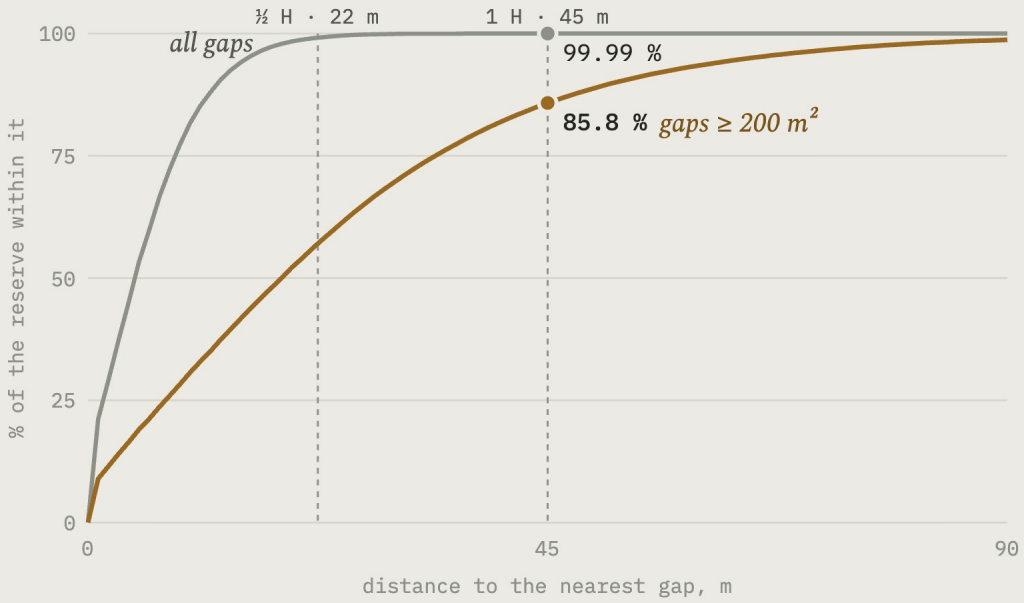




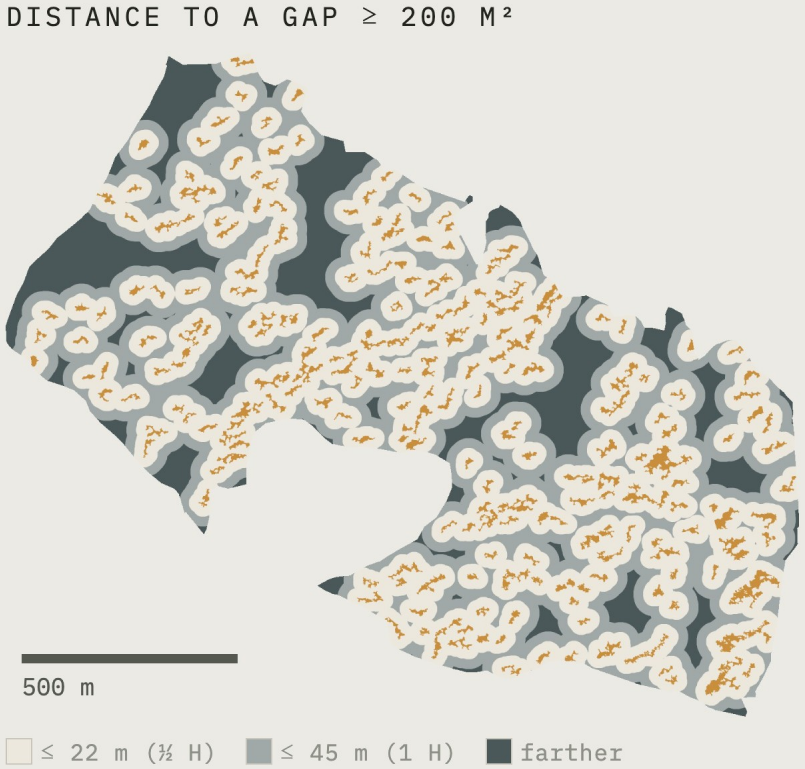
Within 5 m of the ravine centre line, gap fraction is **19 %**, against **11 %** on ridges; at 30–50 m it falls to **12 %**.

> Gap fraction is raised inside the ravines and just beside them. Three readings fit: the canopy surface follows the incision, trees along the stream die more often, or our method reads the ravine's deeper shade as gap.

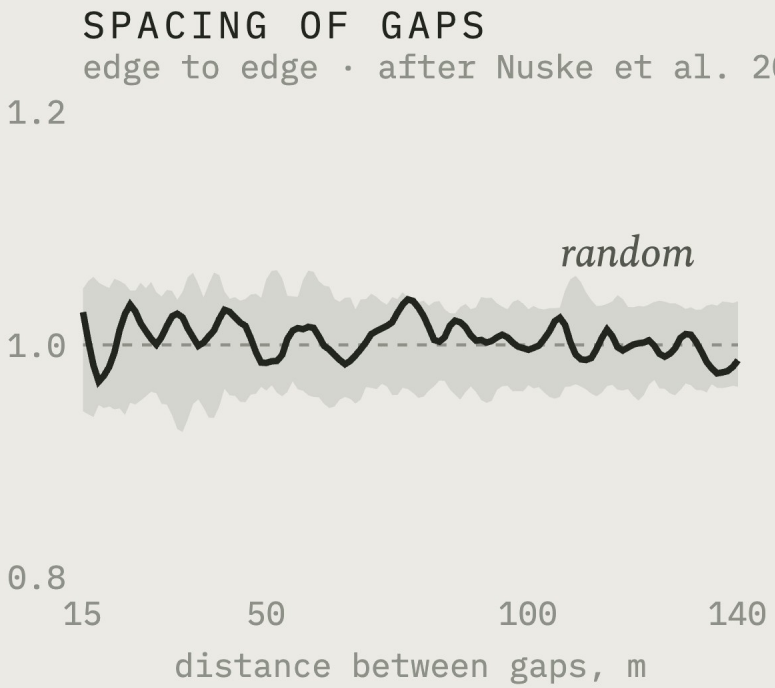
All the canopy lay within one tree height of a gap — 86 % of a gap ≥ 200 m²



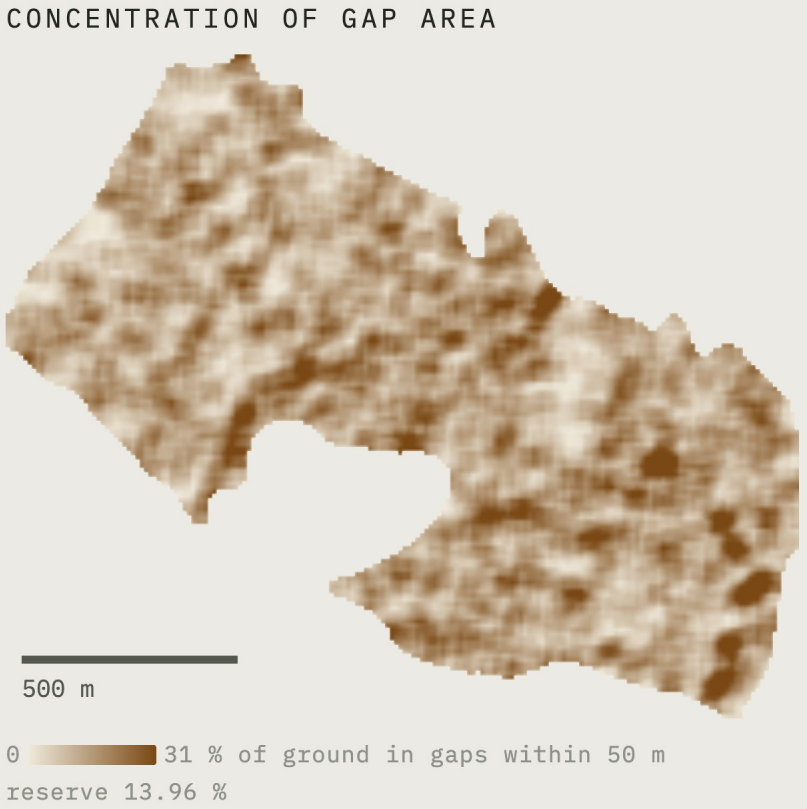
Small gaps reach everywhere; gaps ≥ 200 m² leave blocks of the stand more than a tree height away.
Distances in canopy heights, *H* = 45 m, measured in this reserve *(Drössler & von Lüpke 2005)*.



Gaps formed independently of one another



within the random range
(global test p = 0.41)



> Between 15 and 140 m, the gaps are spaced as if placed at random — no clustering, no regular spacing.

The 1975 canopy points to fine-scale gap dynamics

GAP FRACTION SLIDE 10	**13.96 %** of the reserve — 1 996 gaps, 13.8 per hectare.
SIZE DISTRIBUTION SLIDE 11	**71 %** under 100 m^2; the largest **0.27 ha** — nothing stand-replacing.
ARRANGEMENT SLIDE 15	Spaced **as if at random** between 15 and 140 m (p = 0.41).
DISTANCE TO A GAP SLIDE 14	**All** the canopy within one tree height (45 m) of a gap; **86 %** of a gap ≥ 200 m^2.

> Fine-scale gap dynamics: a canopy opened mostly by one or a few trees at a time, in gaps that formed independently of one another.
> With the same settings, other reserves can be compared.

One cell to set, then Run All

§3 · SET UP YOUR RUN — UC2_POLONINY_CANOPY_GAPS_1975.IPYNB

```
SRC   = DATA_DIR / "Havesova.tif"     # raster, already clipped to the reserve
LABEL = "Havesova"                    # goes into every output filename

GAP_MIN_AREA_M2 = 20                  # smallest gap mapped, m2

ADD_GAPS          = DATA_DIR / "add_gaps.shp"   # openings the detector missed; None if you have none
REMOVE_GAPS       = None                        # things wrongly called gap

RUN_ARRANGEMENT = True                # section 12, the null model
RUN_APPENDIX    = True                # appendix A, the threshold search
AUTO_INSTALL    = True                # install missing Python libraries automatically (first run only)
```

▶ RUN ALL about 4 minutes · every figure, table and map written to outputs/

1. **Set the path to your image**
   one panchromatic raster, clipped to the reserve. No elevation model, no field data.
2. **Run All**
   on the EOSC EU Node everything is already installed; elsewhere, missing libraries install themselves on the first run.
3. **Correct by hand, if needed**
   polygons drawn in GIS are added or erased before anything is measured.

> Every other method setting has a default, and every setting is written into the results.

What you get from one run of the notebook

FOR THE REPORT

A map of every gap — `01_gap_map.png`

the gap map at 0.5 m, and the same map coloured by size class — both at print scale.

The numbers to report — `stats.csv`

13.96 % gap fraction, 1 996 gaps, 13.8 per hectare, median 50.5 m^2 — together with every setting that produced them.

The size reading — `size_classes.csv`

5 size classes and a concentration curve: **71 %** of the gaps are under 100 m^2 and hold 31 % of the gap area.

Distance to a gap — `influence.csv`

how far canopy stands from the nearest gap, metre by metre out to 60 m, with the censored share beside it.

FOR FURTHER ANALYSIS

The gap polygons — `uc2_gaps_<site>.gpkg`

1 996 of them, 8 attributes each — area, perimeter, shape, local brightness, class, detected or drawn by hand.

The gap raster — `gap_map.tif`

the same mask at 0.5 m, to overlay or to feed another stack.

What the detector sees — `anomaly.tif`

the illumination-corrected image, and the 150 m median field it was corrected by.

The range around every number — `threshold_scan.csv`

the whole map recomputed at 14 marks along the brightness axis and at 5 size floors.

Arrangement — `pair_correlation.csv`

the spacing curve with its random envelope, and the share of ground in gaps within 50 m as a raster.

FIGURES, PRINT SCALE

`01_gap_map` · `07_sizeclass_map` · `02_size_distribution` · `10_concentration` · `09_influence` · `11_opening_surface` · `12_arrangement`

Thank you for your attention

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Sources

The detection method — the illumination normalisation, the value-anchored mark, the cleaning rule — is **our own**. These are the values and methods taken from published work.

THE FOREST

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Kucbel S., Jaloviar P., Saniga M., Vencurik J. & Klimaš V. (2010) Canopy gaps in an old-growth fir-beech forest remnant of Western Carpathians. *Eur. J. For. Res.* 129: 249–259.

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Software — NumPy (Harris et al. 2020), SciPy (Virtanen et al. 2020), scikit-image (van der Walt et al. 2014), Matplotlib (Hunter 2007), pandas (McKinney 2010), scikit-learn (Pedregosa et al. 2011), rasterio, GeoPandas, Shapely, pyproj. · **Data** — KH-9 HEXAGON, USGS EROS (public domain); Slovak old-growth reserve outlines; 1 m DEM, ÚGKK SR, validation referee only.