D-Mosaic 40 Years Timeline for Germany

The “Germany Mosaic” is a time series from 1984 to 2025 of satellite image data for the whole of Germany.

Content

Each year is represented by two 6-band color images for summer and autumn, polygons with natural boundaries and attributes for 34 spectral and geometric properties (Fig. 1) and an elevation model. The area is divided into 54 tiles 120×120 km with 20 km overlap (Fig. 2).

Sensors:

TM, ETM and OLI (spectral) on Landsat 4, 5, 8, 9
TIRS (thermal) on Landsat 4, 5, 8, 9
ASTER (elevation) on Terra

Projection:

All products are projected according to UTM, WGS84, Zone 32 (EPSG 32632)

Fig. 1:
Vector representation of the D-Mosaic with colorized attributes of three basic traits:

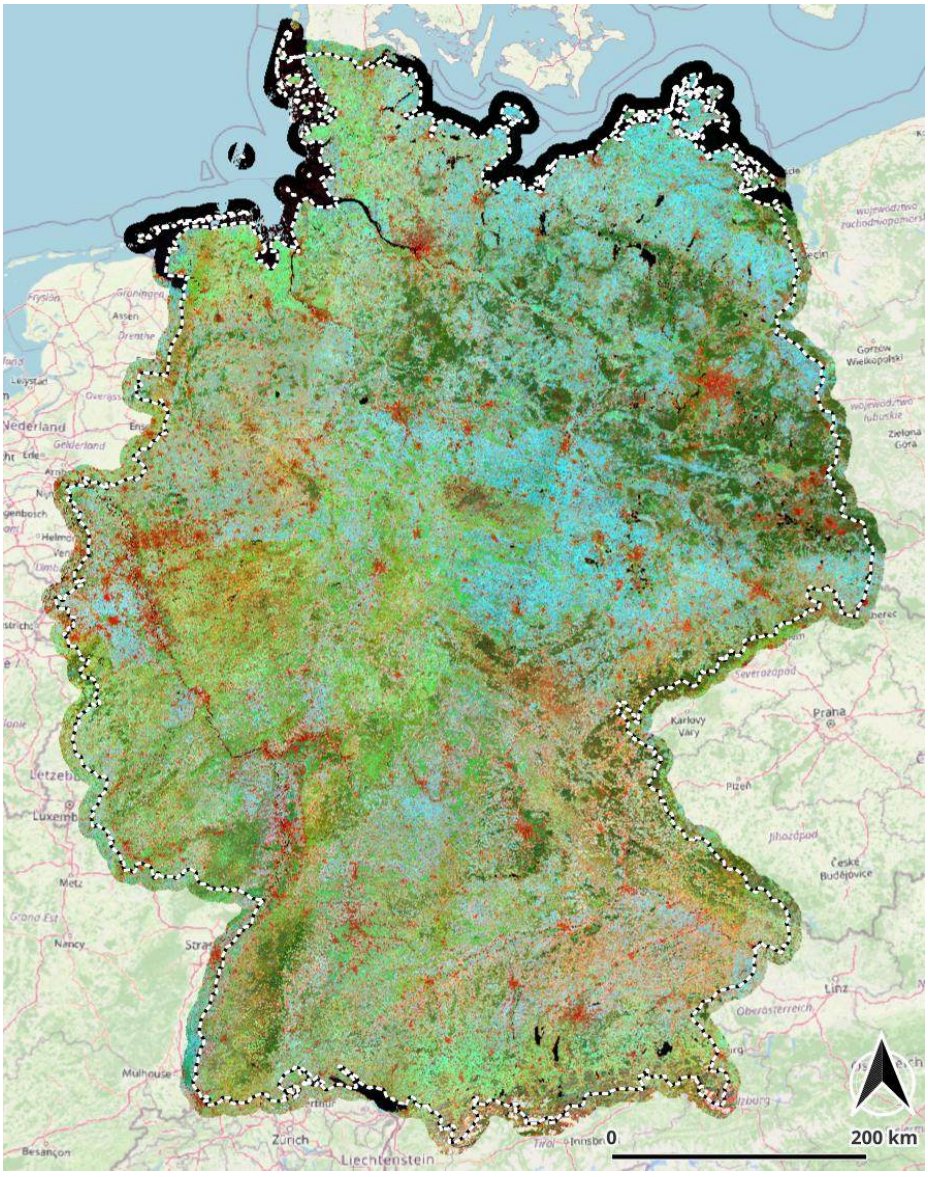
Red: *Structural diversity (texture) within zones*

Green: *Metabolic rate of green plants as vegetation index NIRv*

Blue: *Seasonal variation (summer–autumn) based on time series*

Black: *Zone boundaries (not visible at this magnification, see Fig. 2)*

Sensor: Landsat 8/9
Mai – October 2023



Tile Selection

The map area is divided into 54 tiles, which together cover all of Germany in a regular 100x100 km grid. The edges of the tiles overlap by 20 km.

To find the appropriate tiles, first load dMos_tiles.shp from the “meta” directory. The vector layer contains the boundaries, overlap, ID, and quality of all tiles in the D-Mosaic. Then navigate to the root directory ›D-Mosaic_Root‹. There you will find directories for all tile IDs. Each directory contains ZIP archives for one year each, containing all raster and vector data of the mosaic. The ZIP archives can be downloaded directly.

The elevation data can be found in the D-Mosaic_DTM directory under the same tile ID as the image data. They are also available as attribute of the vector data.

Fig. 2:
Tile Numbering

54 Tiles are numbered systematically in 7 cols and 9 rows.

Each year from 1984 until 2025 is stored in its own archive.

Elevation data are available once for all years with he same tiling.

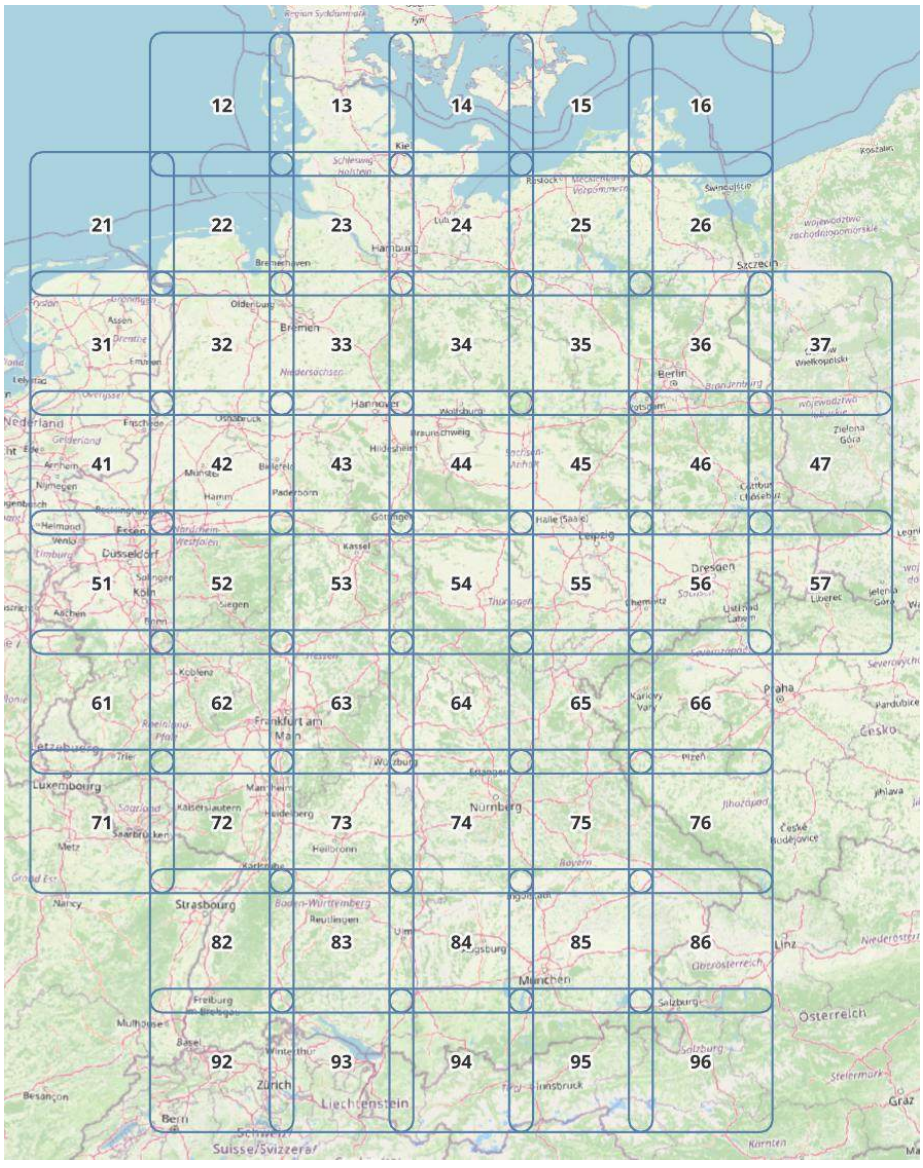


Image Products

Five image products from Landsat Sensors TM, ETM and OLI are available for each time period. In some cases the thermal bands (B10) are also provided as raster images. An elevation model from Aster on Terra is provided for all tiles once for all years.

BRD-Tile_AIR_Date	Vegetation seasonal change color composite
BRD-Tile_B2-7_Date	6 band optimized color composit for Mai to July
BRD-Tile_B2-7_Date	6 band optimized color composit for August to October
BRD-Tile_QA_Date	Number of accepted images for each pixel (May to July)
BRD-Tile_QA_Date	Number of accepted images for each pixel (Aug. to Oct.)

“Tile” and “Date” refer to the individual tile-ID and the date

BRD-Tile_DTM	Elevation model for all tiles

BestOf: The image data shows the most frequent value from a time series of three months. With three or more images, the process uses the median. With two images, it uses the mean value or only the value of the “better” image if the overall quality of the images differs by more than 20%.

Clouds: Clouds are eliminated in two ways. First, Landsat data are supplied with a high-quality cloud mask. Clouds classified as “certain” are ignored. Clouds and cloud shadows lie at the boundaries of the brightness distribution. The median (BestOf) takes the values in the middle of the distribution.

The optimization is calculated individually for each pixel. Since clouds are rarely stationary, even heavily clouded images from different dates can be combined to form cloud free images.

Spectral ranges: The values of the image products are calibrated to TOA reflectance. The NASA gives the following values for the spectral ranges of the OLI / TIRS sensor respectively:

The bandwidths of the OLI sensor (Landsat 8, 9) are largely the same as the older TM and ETM sensors that were in use until 2011. Only the near infrared band is considerably narrower with the OLI sensor than for the TM and ETM sensors:

Elevation: The elevation data (AST14DEM products) is provided once for all years in the separate “DEM” directory.

Tab.1a:

Band name	calibration	spectral range
B2 (OLI: blue)	surface reflectance	0.452 - 0.512 µm
B3 (OLI: green)	surface reflectance	0.533 - 0.590 µm
B4 (OLI: red)	surface reflectance	0.636 - 0.673 µm
B5 (OLI: near infrared)	surface reflectance	0.851 - 0.879 µm
B6 (OLI: shortwave infrared 1)	surface reflectance	1.566 - 1.651 µm
B7 (OLI: shortwave infrared 2)	surface reflectance	2.107 - 2.294 µm
B10 (TIRS: thermal)	surface reflectance	10.600 - 11.190 µm

Tab.1b:

Band name	calibration	spectral range
B4 TM/ETM (near infrared)	surface reflectance	0.77-0.90 µm

Tab.1c:

AST14DEM	ASTER Digital Elevation Model V003

Vector Products

Zones: The landscape model is based on zones. Zones are largely homogeneous image patches that are represented as polygons. The underlying algorithm minimizes the variance of pixels within individual zones [5].

Indicators: The attributes of the zones describe the characteristics of the pixels within the zones (spectral combinations, indices, gradients, elevation, temperature), the characteristics of the zones themselves (shape, size), the characteristics of the zone environment (contrast, contacts) [4].

Seasons In Central Europe, the changes in the appearance of the landscape between different seasons are greater than the differences between years at the same season. The D-Mosaic therefore contains separate products for the first and second half of the growing season, May to July (summer) and August to October (autumn). Both periods together cover the half of the year in which the vegetation index in central Germany exceeds the half-maximum value (Abb. 3).

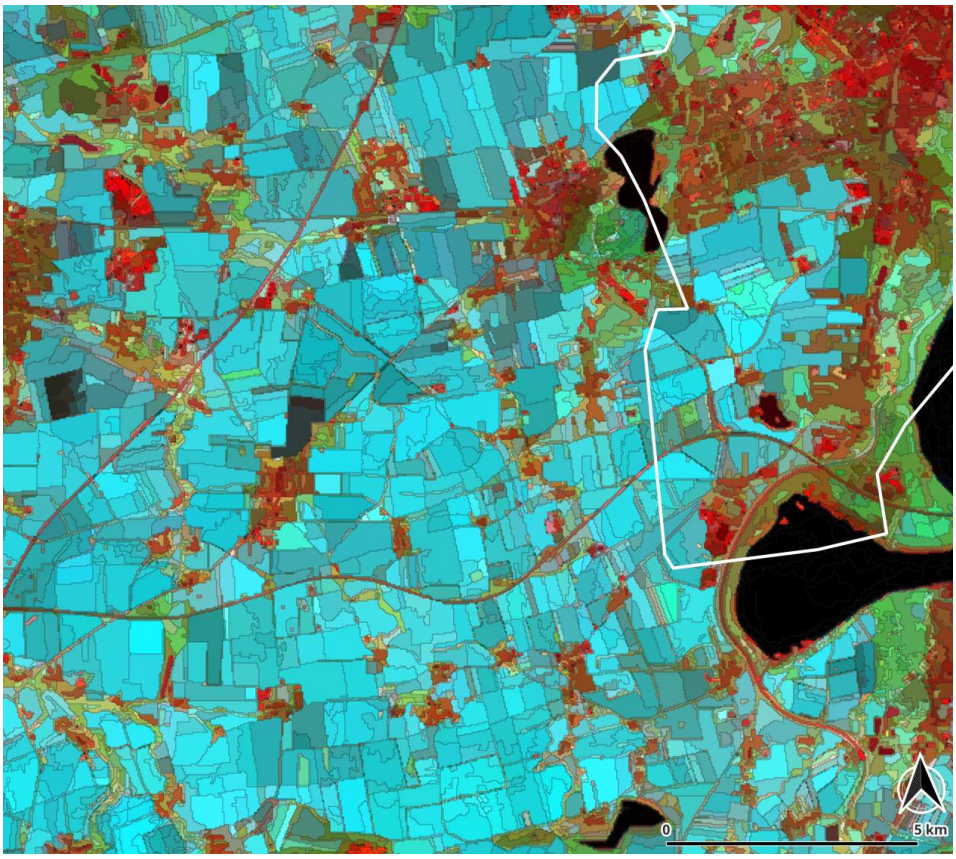
Naming Zones cover one year each, while image data are separated for summer and autumn. Summer characteristics are marked with a superscript “2” (second season), fall characteristics with a superscript “3” (third season).

***Fig. 3: Detail from Fig. 1 showing the clearly visible boundaries of the zones**.*

In the blue-green area (high metabolic rate and significant seasonal variation), the zones are particularly visible.

At the bottom edge in the center of the image, variations in soil moisture have created boundaries that differ markedly from land use patterns.

SW of Leipzig, Germany (white line), summer 2023



Structures

Pixel structures within individual zones such as “entropy” or “texture” are not separated by seasons. Shape and environmental characteristics of entire zones are independent of the seasons and are also specified only once.

Fieldnmes

Indicators:

Geometry:

WKT	Coordinates of the polygons (zones)
DN	Consecutive zones ID

Pixel-Reflection:

blue²…MIR²	Landsat bands B2…B7 TOA reflectance; May…July
blue²…MIR²	Landsat bands B2…B7 TOA reflectance; August… October

The abbreviations “blue”, “green”, “red”, “NIR”, “SWIR”, and “MIR” refer to the six optical bands (2 through 7) of the OLI sensor (on Landsat 8/9). These designations have also been applied to the corresponding bands of older sensors (TM and ETM on Landsat 4–7).

Spectral characteristics are recorded as the arithmetic mean of all pixels in individual zones. The same applies to indices such as the NDVI (vegetation index). All other indicators are defined in detail in the imalys GIT [1]

The seasons are represented by two separate recording periods. Together, they make up two equal halves of the growing season from May through October. The superscript (such as red², red³) indicates summer and fall the second and third quarters of the year.

Pixel-Indicators:

NDVI²	Normalized Density Vegetation Index: May…July
NDVI³	Normalized Density Vegetation Index: August…October
NIRV²	Near Infrared Reflection of Vegetation: May…July
NIRV³	Near Infrared Reflection of Vegetation: August…October
AIR-max	Highest NIRV value throughout the vegetation period
AIR-min	Lowest NIRV value throughout the vegetation period
AIR-range	Absolute difference between AIR-min and AIR-max

The Normalized Vegetation Index **NDVI** is calculated according to the usual formula (below). The "Near Infrared Reflection of Vegetation" (**NIRV**) extends this definition to allow a better estimation of the Solar Induced Chlorophyll Fluorescence (SIF) [2][3][6].

NDVI: $\frac{(N-R)}{(N+R)}$ NIRV: $\frac{(N-R)}{(N+R)} \cdot N$

N: Band 5 (near infrared); R: Band 4 (red)

Fig. 4: Annual Vegetation Dynamics

Vegetation Index NIRV for the years 2010-2020 from MODIS (on Terra) data shown as an annual periodicity.

The dry year 2018 is highlighted in color (green). The data is based on natural green spaces in the Leipzig area.

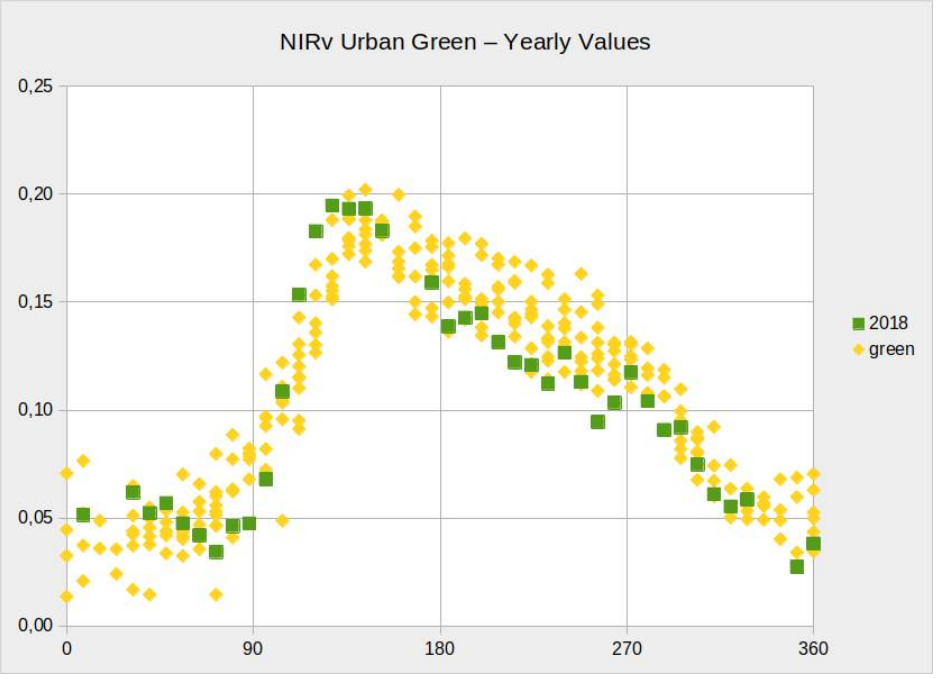
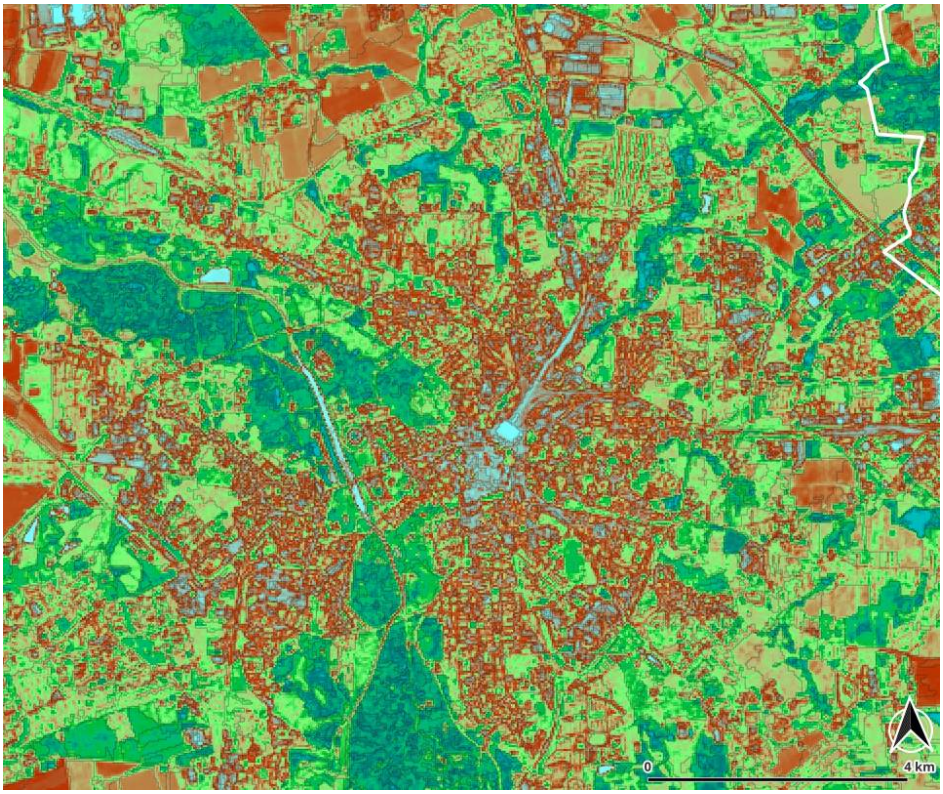


Fig. 5: Vegetation Index NIRv

The “Near Infrared Radiation Vegetation” index tries to return the Photosynthetic Active Radiation (PAR). As the NDVI is a proxy of vegetation density the NIRv estimates the metabolic activity. This image shows the status of the early summer.

City of Leizig
May to July 2019X



AIR-max denotes the highest value of the metabolic rate NIRV within the entire vegetation period (May to October). The AIR-max values can be used as an indicator of permanent sealing, but are also sensitive to drought stress, degradation or reduced vitality for other reasons.

AIR-min denotes the lowest value of the metabolic rate NIRV within the entire vegetation period (May to October). The minimum corresponds to the proportion of permanent greenery in the landscape.

AIR-range denotes the absolute difference between AIR-min and AIR-max within the vegetation period (May to October). High values are specific to strong (anthropogenic) changes, e.g. due to agriculture.

Pixel-Properties:

Kelvin²	Thermal Infrared, given as [K]: May…July
Kelvin³	Thermal Infrared, given as [K]: August…October
DTM	Digital Terrain Model height given as [m]
QA²	Number of usable images: May…July
QA³	Number of usable images: August…October

Kelvin denotes the absolute temperature (in Kelvin) at 1 m above ground. The measure is taken at about 9:20h in the morning.

DTM denotes then mean height of individual zones from the Digital Terrain Model of the ASTER sensor on Terra with 1'' spatial resolution (approx. 30m).

QA is defined as the number of accepted source images per pixel. The provided value is the mean for each zone.

For the D-Mosaic, all raw data with at least 50% clear pixels were combined into one product for 3 months each (May to July, August to October). In some cases parts or even the whole image tile must be rejected due to the low proportion of covered pixels.

Structural:

Cellsize	Size of the zones given as [ha]
Dendrites	Quotient of zone perimeter and cellsize
Diversity	Spectral diversity of the central zone and all neighbors
Proportion	Size diversity of the central zone and all neighbors
Relation	Quotient of neighbors and perimeter of one zone

The **size** of the zones is calculated as the sum of all pixels covering the zone. The values are given as Hectares [ha] (100m × 100m).

The **dendrites** process returns the quotient between perimeter and size of single zones. It emphasizes a small or dendritic form of the zone. Both values grow with larger zones but the size grows faster. Large zones will show lower values than smaller ones with the same shape.

The **diversity** between zones is calculated as the statistical deviation of all spectral attributes between the central zone and all its neighbors. As the zones might differ considerably in size and shape the length of the common border was selected as a measure for the contribution of the different zones to the final value.

The **proportion** process calculates the relation between the size of the central zone and the mean size of its neighbors. Values around one indicate equally sized neighbor zones.

Relation is calculated as the relation between the number of neighbor zones and the perimeter of the central zone. Like dendrites also relation returns information about the shape and the connection of the zones.

Pixel-Statistics within zones:

Entropy*	Rao’s Entropy or pixel deviation within zones
Normal	Texture with brightness normalized values
Texture	mean difference between all pixel neighbors

**exchanged by “diversity” in newer versions*

The **entropy** process returns the spectral deviation of all pixels within one zone. For multispectral images the deviation is calculated independently for each band and the first principal component of all deviations is taken as the final result. The entropy values are calculated using the Gauss’s formula for deviation.

As the texture process does, **normal** returns the mean difference between all pixel pairs within a single zone but in this case the difference is normalized by the mean brightness of the compared pixels.

Citations

[1] GitLab: https://codebase.helmholtz.cloud/esis/imalys
or GitHub: https://github.com/c7sepe2/Imalys_ESIS-Software-Tools-v0.3

[2] G. Badgley, C. B. Field, J. A. Berry, Canopy near-infrared reflectance and terrestrial photosynthesis. Sci. Adv. 3, e1602244 (2017).

[3] M. Marshall, E. Okuto, Y. Kang, E. Opiyo, and M. Ahmed: Global assessment of Vegetation Index and Phenology Lab (VIP) and Global Inventory Modeling and Mapping Studies (GIMMS) version 3 products, Biogeosciences, 13, 625-639, https://doi.org/10.5194/bg-13-625-2016, 2016

[4] Selsam, P.; Bumberger, J.; Wellmann, T.; Pause, M.; Gey, R.; Borg, E.; Lausch, A. Ecosystem Integrity Remote Sensing — Modelling and Service Tool — ESIS/Imalys. Remote Sens. 2024, 16, 1139.

[5] Angela Lausch, Peter Selsam, Jan Bumberger: Conceptual framework for hybrid landscape modelling: The pixel–zone–object approach and its theoretical foundations. Ecological Indicators 183 (2026) 114679, https://doi.org/10.1016/j.ecolind.2026.114679

[6] Gina H. Mohammeda & Co: Remote sensing of solar-induced chlorophyll fluorescence (SIF) in vegetation: 50 years of progress; Remote Sensing of Environment 231 (2019) 111177