A research institute
of the ETH Domain

Ecological infrastructure planning

Using R for geospatial data processing & analysis

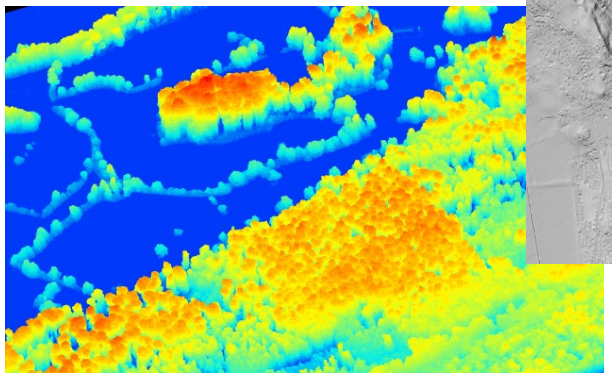
Zurich R User Meetup, 23.01.2025 – Dominique Weber, Remote Sensing Group

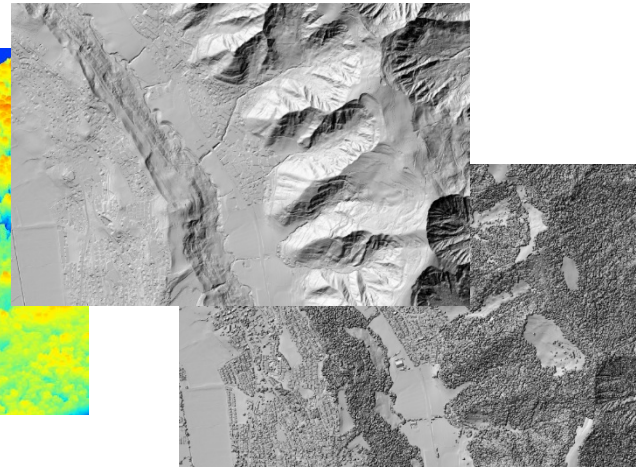
Swiss Federal Institute for Forest, Snow
and Landscape Research WSL

Remote sensing and spatial data

Imagery (raster data)

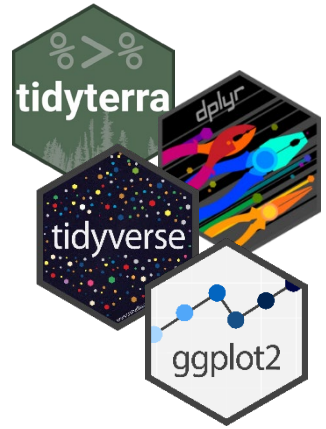
Point cloud data (X, Y, Z)



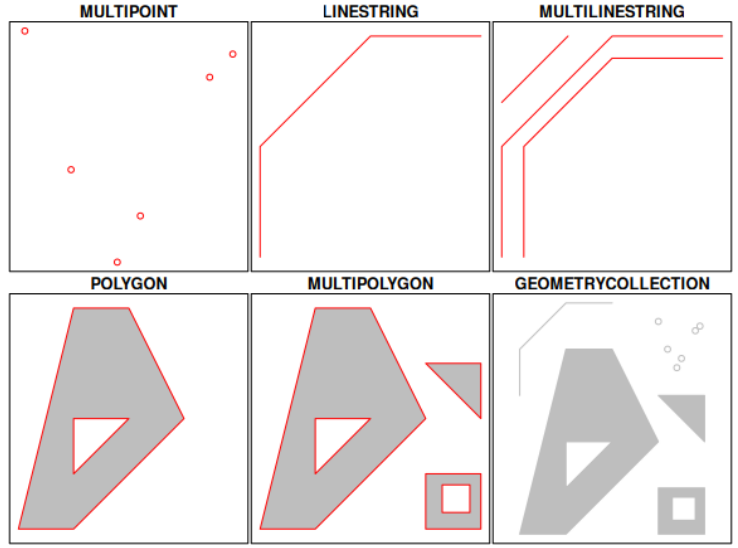


© swisstopo, ESA/Copernicus

R packages

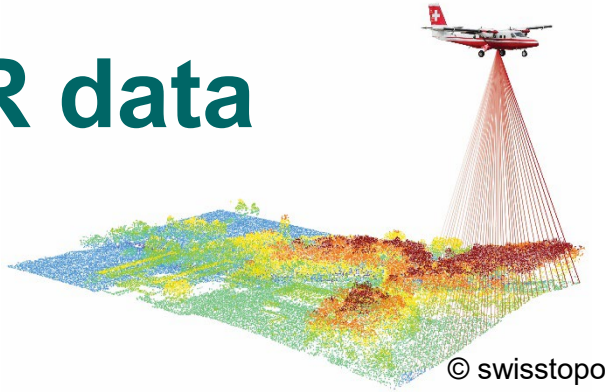


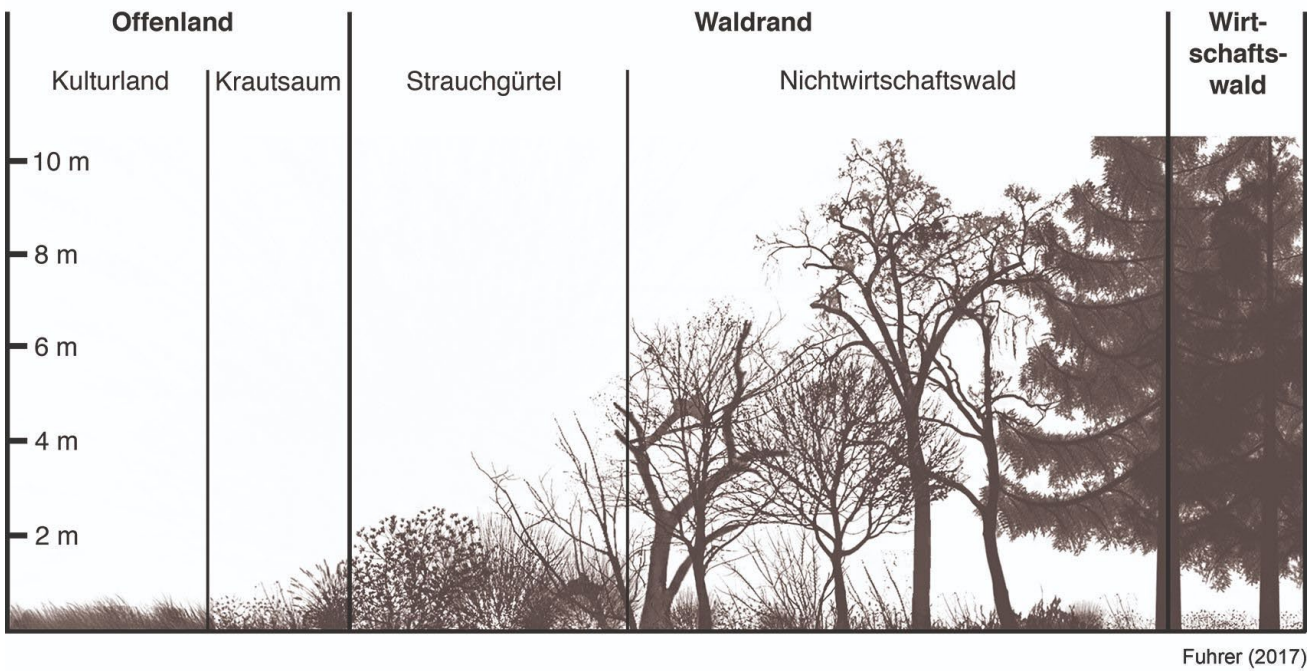
Vector data



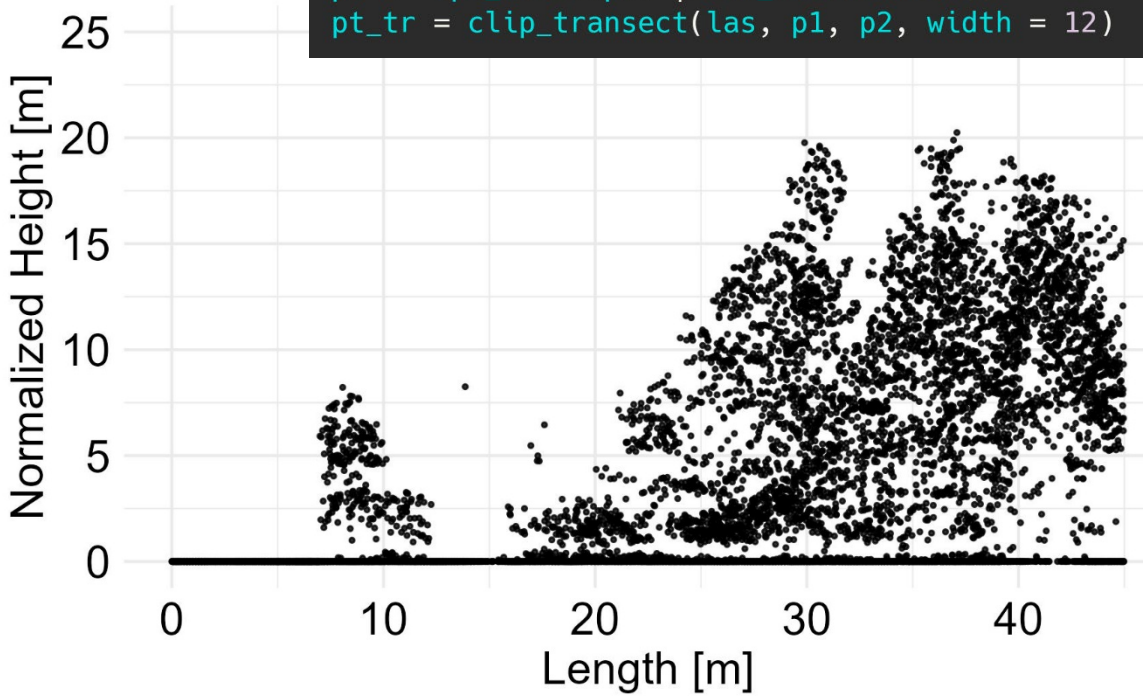
https://cran.r-project.org/web/packages/sf/vignettes/sf1.html

Edge zone characterisation from LiDAR data



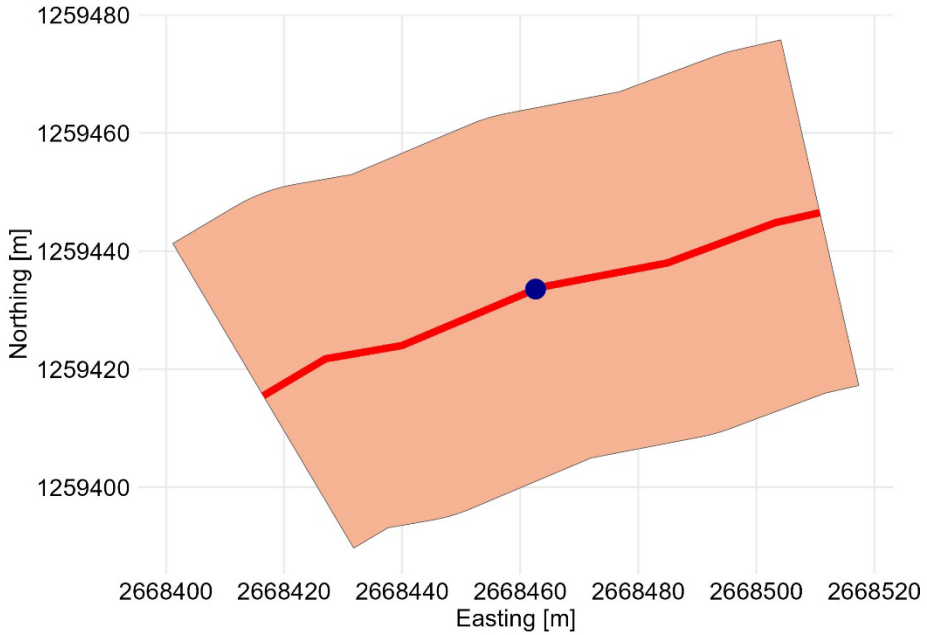



```
p1 <- lp1_list[[p]] |> st_coordinates()
p2 <- lp2_list[[p]] |> st_coordinates()
pt_tr = clip_transect(las, p1, p2, width = 12)
```

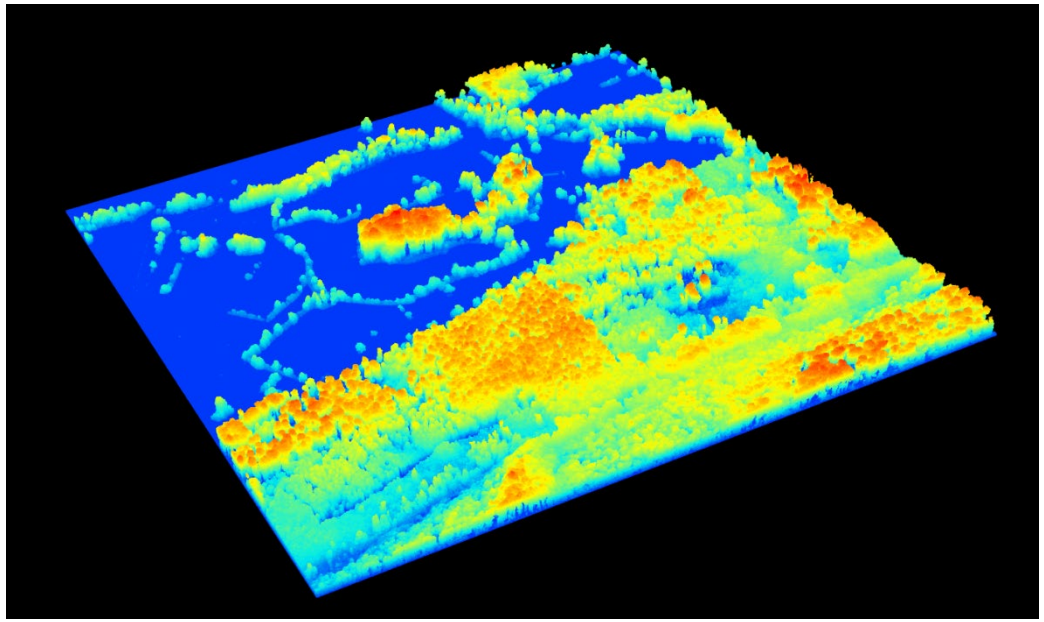


Contact: Moritz Bruggisser

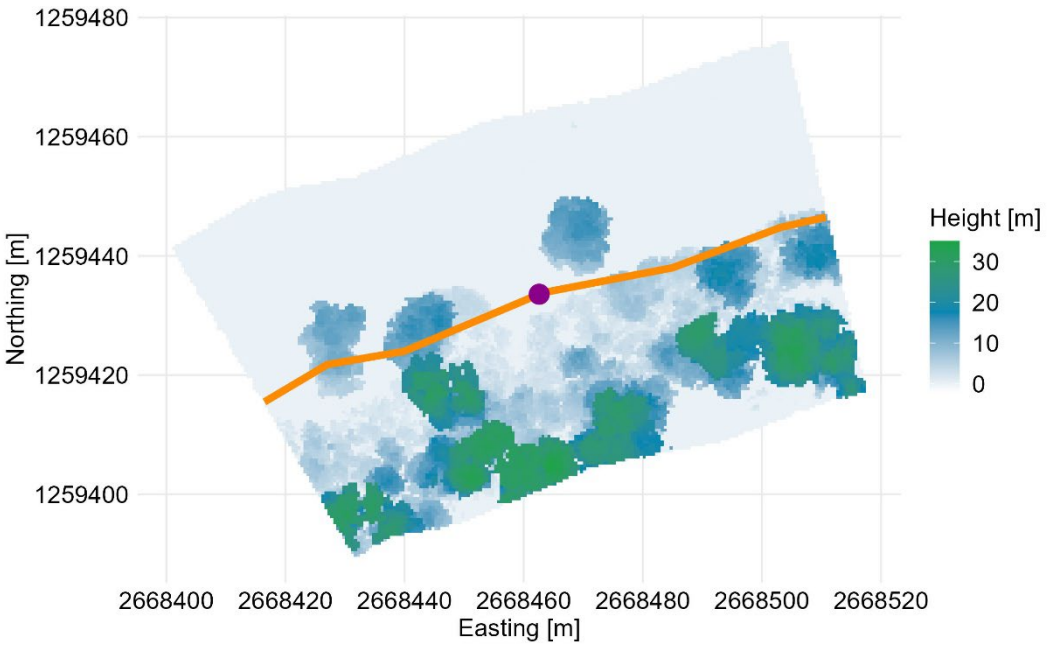
Forest edge zone (shapefile)



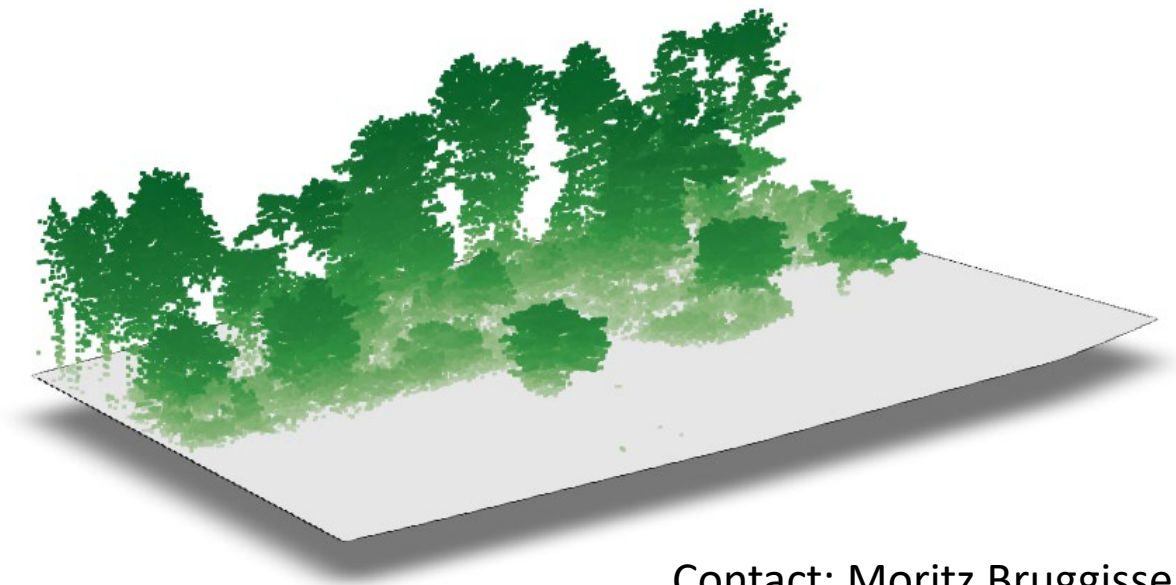
1km^2 point cloud tile



Canopy height model

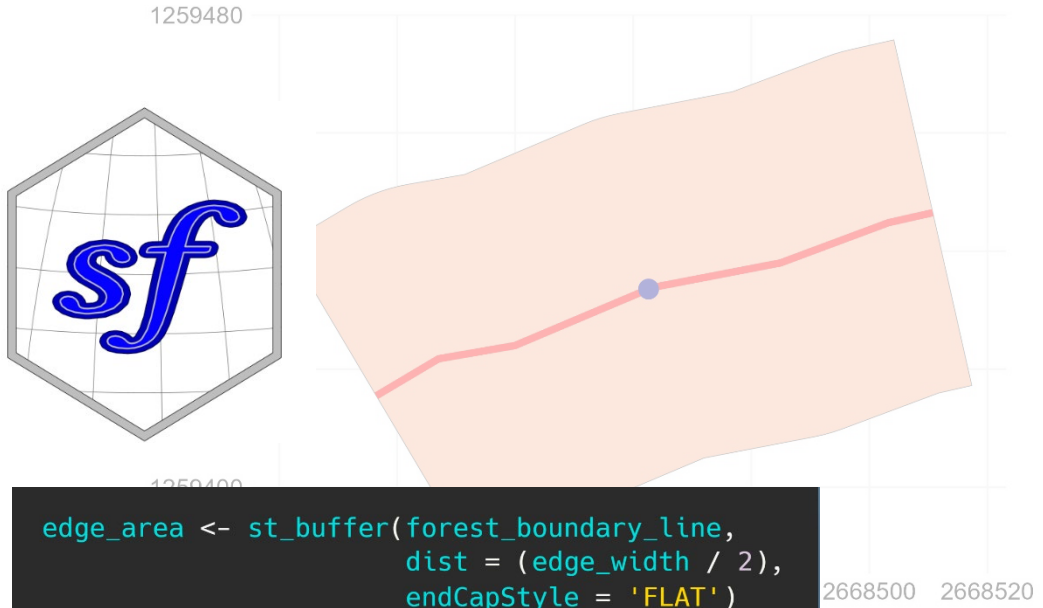


Point cloud, clipped to edge zone



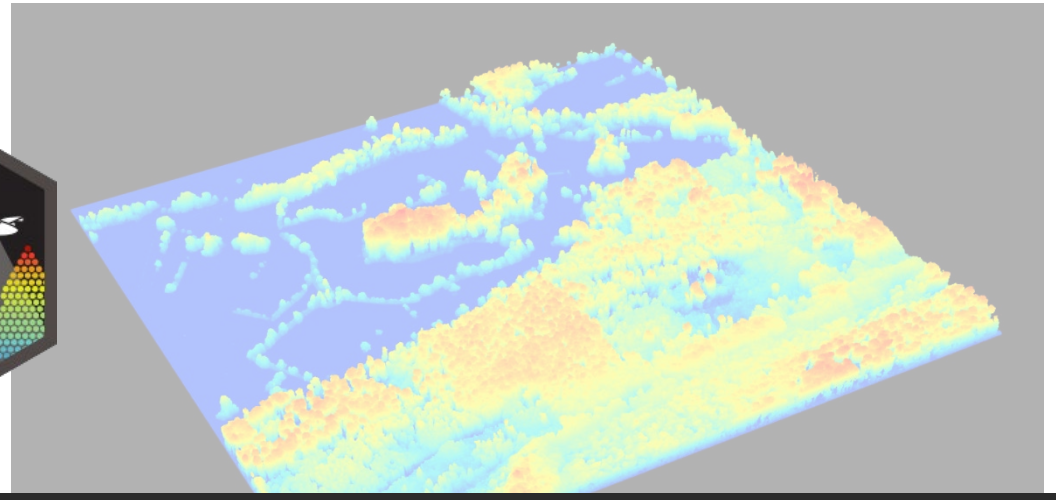
Contact: Moritz Bruggisser

Forest edge zone (shapefile)



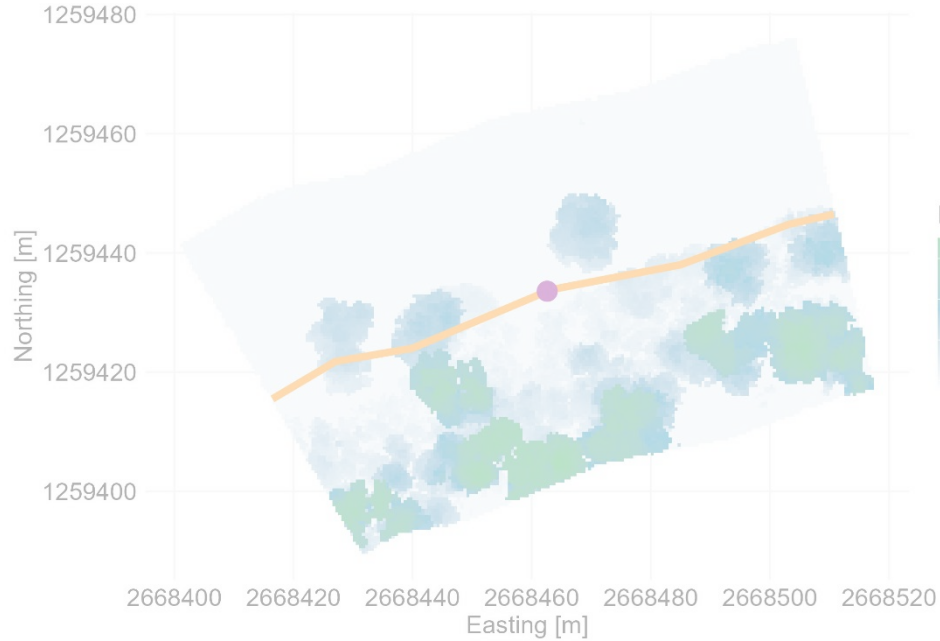

```
edge_area <- st_buffer(forest_boundary_line,
                       dist = (edge_width / 2),
                       endCapStyle = 'FLAT')
```

1km² point cloud tile



```
# load swissSURFACE3D data (1km2-tile)
las <- readLAS(flas)
st_crs(las) <- st_crs(roi)

# crop to extent of region of interest
las_roi <-  clip_roi(las, roi)

# generate canopy height models, i.e. transform point cloud heights into a
# rasterized height model
chm <- rasterize_canopy(las = las_roi, res = 0.5,
                        algorithm = p2r(subcircle = 0.1))
```

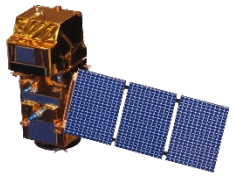
Canopy height model

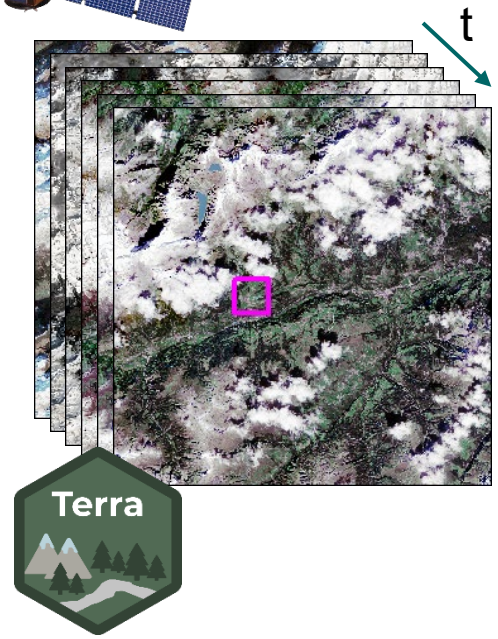


Contact: Moritz Bruggisser

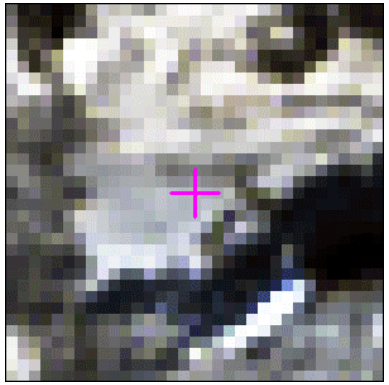
Satellite imagery time series

```
# extract time series per plot
force_ts <- terra::extract(ts, vect(plot))
```

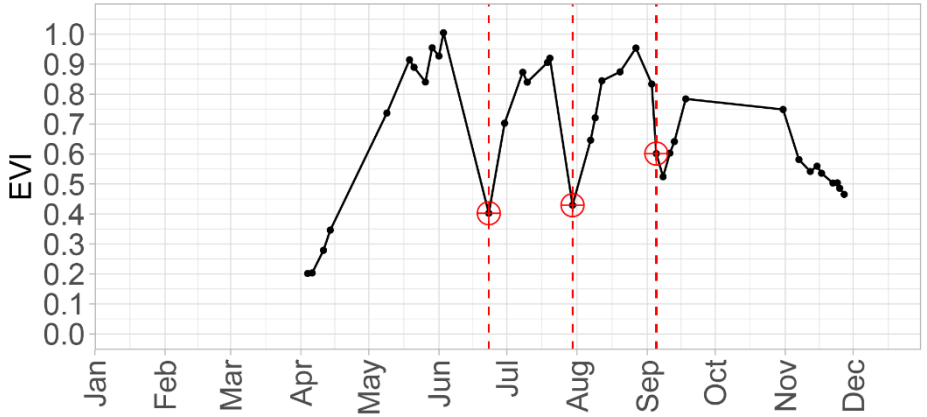




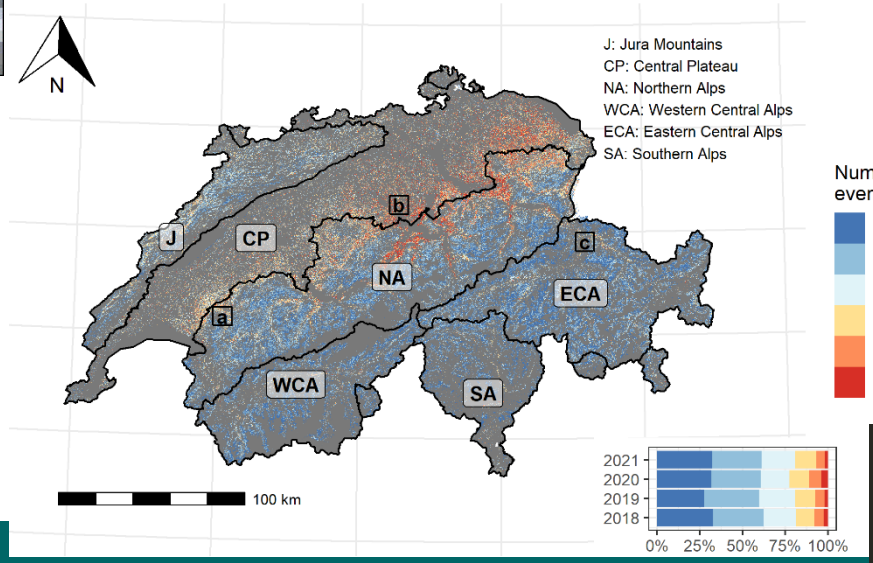
Sentinel-2 time series

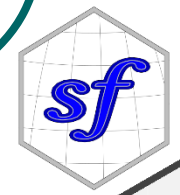


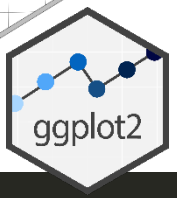
Monitoring the vegetation status



Algorithm to detect mowing events








```
all <- ggplot() +
  geom_sf(data=ch, fill="#797979", colour=NA) +
  geom_spatraster(data = map, maxcell=ncells) +
  scale_fill_manual(values=col, na.value = NA, na.translate=F) +
  geom_sf(data=bgr, fill=NA, colour="black", lwd=0.5) +
```

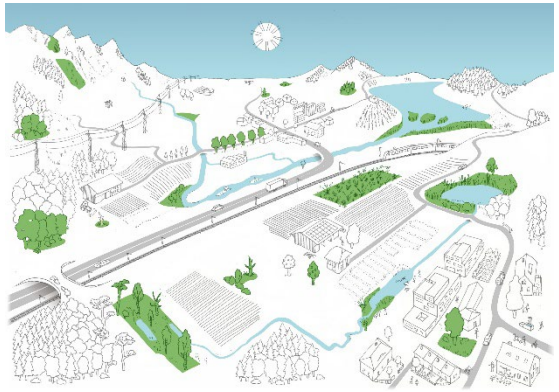
Weber D et al. (2024) Grassland-use intensity maps for Switzerland based on satellite time series: Challenges and opportunities for ecological applications. RSEC, 10(3), 312-327

Ecological Infrastructure

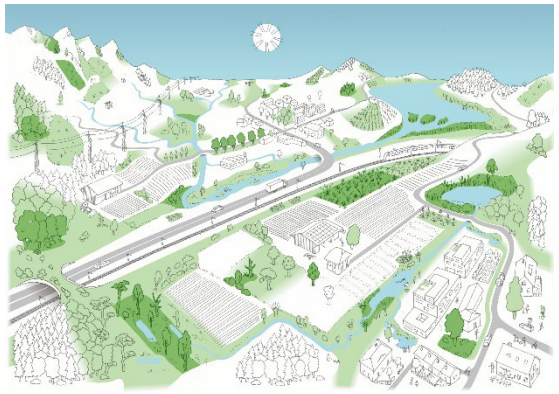
Definition
A nationwide network of natural and semi-natural habitats important for biodiversity with the aim to promote the quality, quantity and connectivity of ecologically valuable habitats in Switzerland.

Implementation
- By 2040, Switzerland should have a functioning Ecological Infrastructure that ensures the long-term conservation of biodiversity
- The cantons are responsible to develop the basis for the implementation (e.g. maps of current situation & future potential).

Today



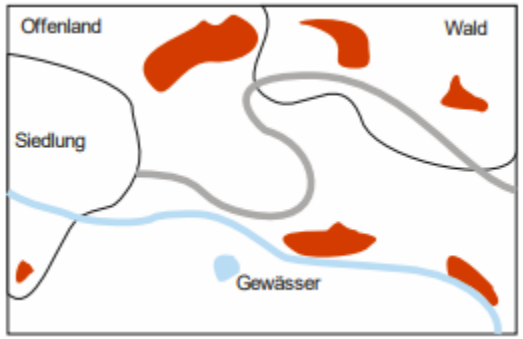
Needed



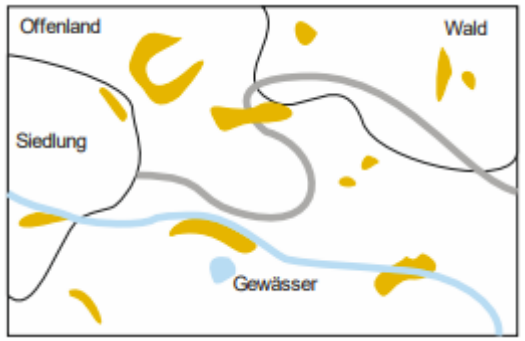
© Fachgruppe Ökologische Infrastruktur
(Graphic: Valentin Rüegg)

Ecological Infrastructure

Core areas



Interconnected areas



Different habitats e.g. dry, wet

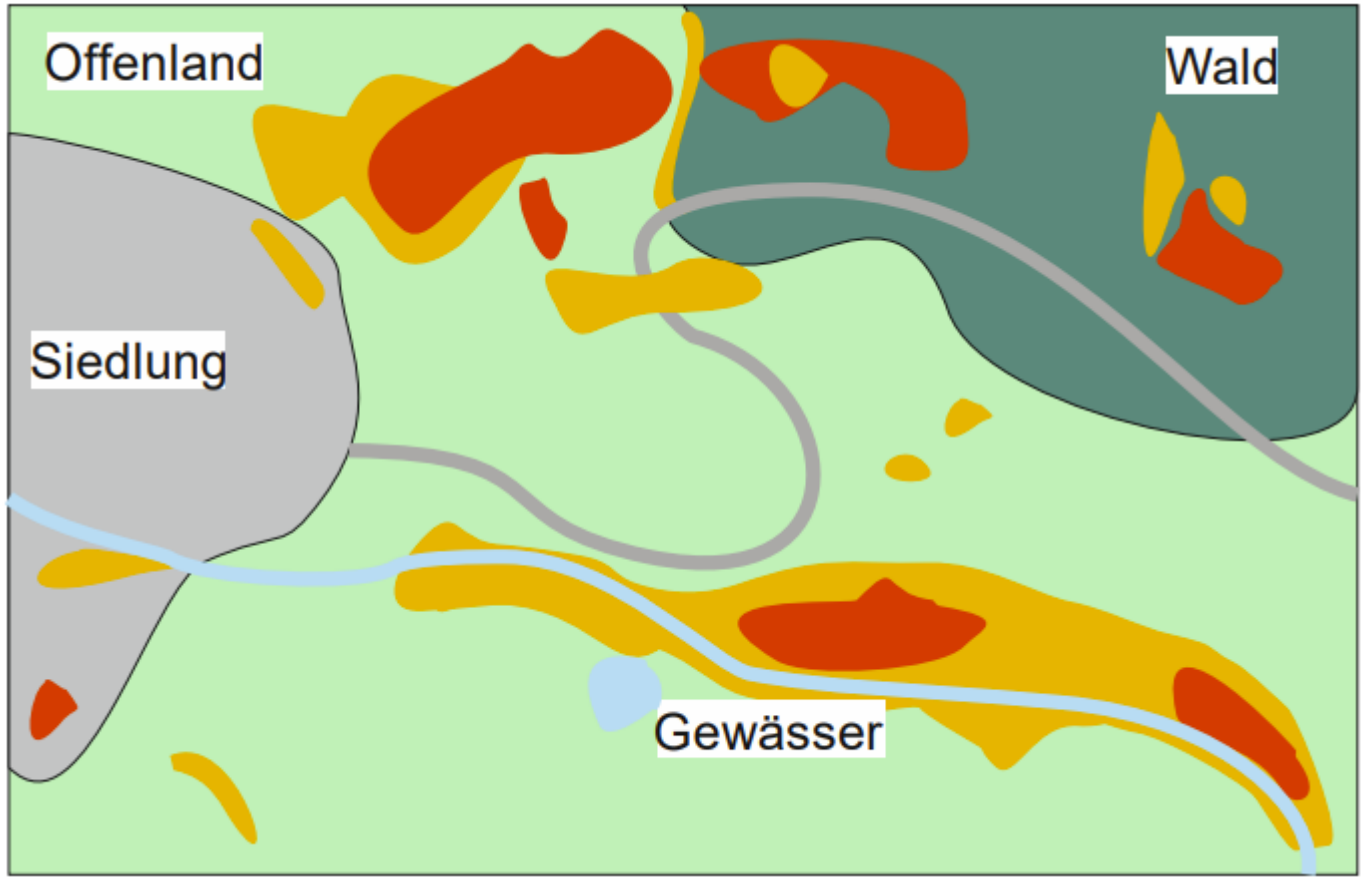
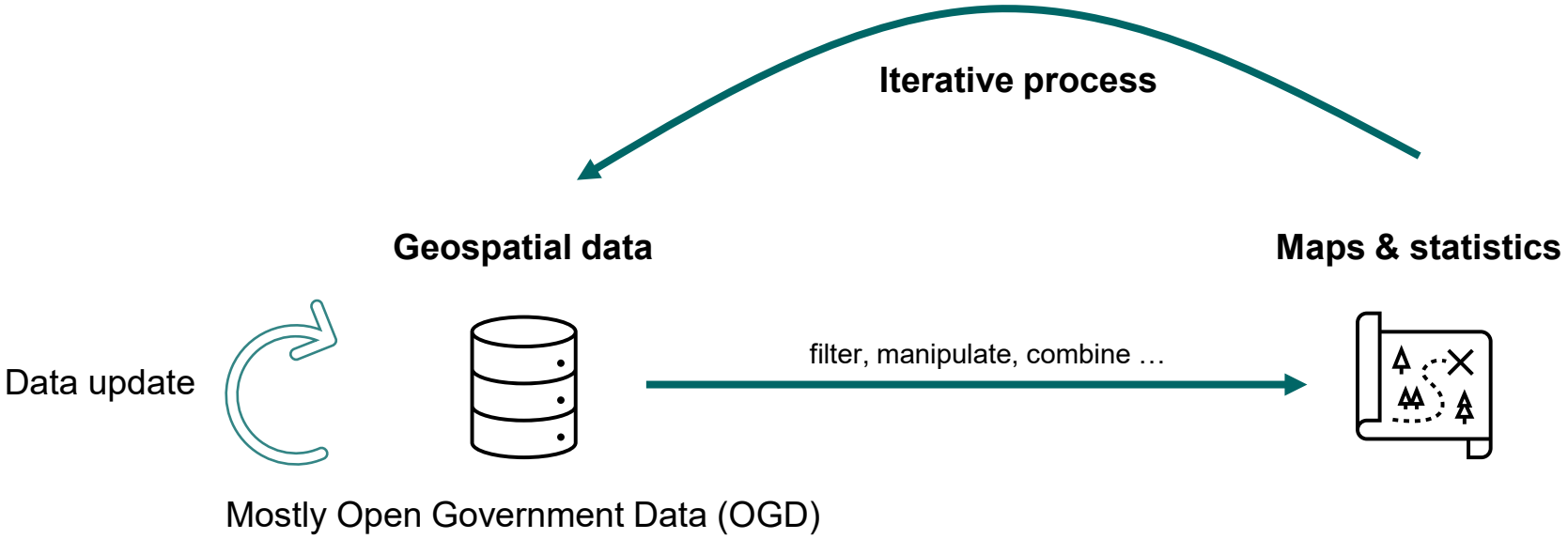


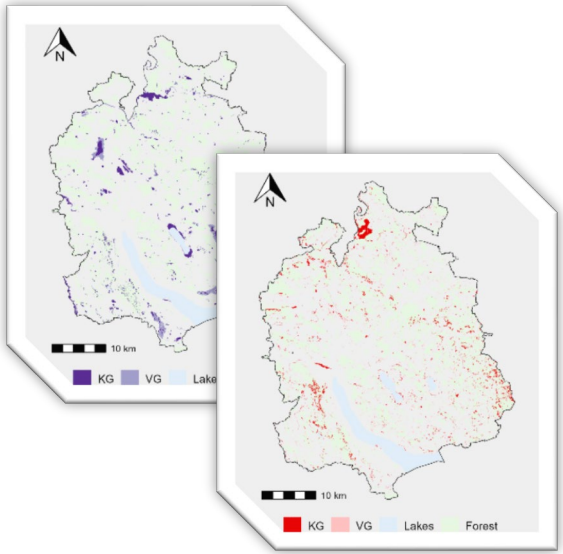
Figure adapted from BAFU Arbeitshilfe v 1.0

Overview – our task

Our task was to support the Canton of Zurich in analysing geospatial data on biodiversity

- to produce maps & statistics on the current situation and future potential
- in a consistent and reproducible way (fully automatic processing pipeline)
- as a spatial basis for the implementation of the ecological infrastructure





Overview (2)

Moore

Zum Schutz der Moore hat der Bund die Hochmoor-, Flachm
Moorlandschaftsverordnung samt Inventaren erlassen. In vi
Gebieten von nationaler Bedeutung sinkt allerdings die ökc
braucht Pufferzonen und Regenerationen. Das BAFU unters
Beiträgen.

Ein ungenutztes Hochmoor (Vordergrund) u
Moorlandschaft Rothenthurm
© Albert Marty

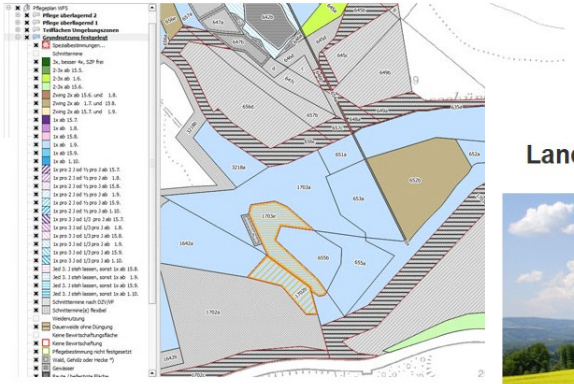
Amphibienlaichgebiete

Die Amphibien sind hierzulande stark bedroht, denn es fehlt ihnen an Tümpeln, Teichen oder Weihern, wo sie laichen können. Um die gefährdeten Amphibien der Schweiz zu schützen, hat der Bund das Inventar der Amphibienlaichgebiete von nationaler Bedeutung in Kraft gesetzt. Es bezeichnet die wichtigsten Fortpflanzungsgebiete.

Amphibien gehören zu den am stärksten gefährdeten Tierarten der Schweiz, da ihnen die Laichgebiete fehlen.
© IANB-Beratungsstelle/Ursina Tobler

Geodatensatz

Pflegeplan und NHG-Beitragsflächen



Geodatensatz

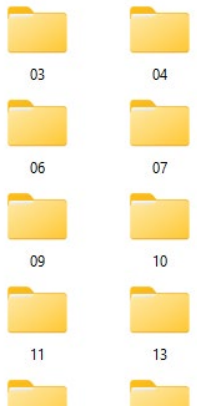
Lichte Wälder

Geodatensatz

Landwirtschaftliche Nutzungsflächen

And many more…

Storing original files as ZIP
(*.SHP, *.GPKG, *.GDB, *.TIF)



Unzip, Clip to ZH, Pre-Filtering, Loading to GDB

Using Python / ArcPy

Further processing and analysis in R

```r
# KG Betrieb
pfpl_f <- st_read(dsn = "data.gdb", layer = "A03_10_Pflegeplan_Feucht") %>%
  st_union() %>%
  st_sf(source="Pflegeplan")
hm <- st_read(dsn = "data.gdb", layer = "A03_01_hm") %>%
  st_union() %>%
  st_sf(source="Hochmoor")
fm <- st_read(dsn = "data.gdb", layer = "A03_02_fm") %>%
  st_union() %>%
  st_sf(source="Flachmoor")
```

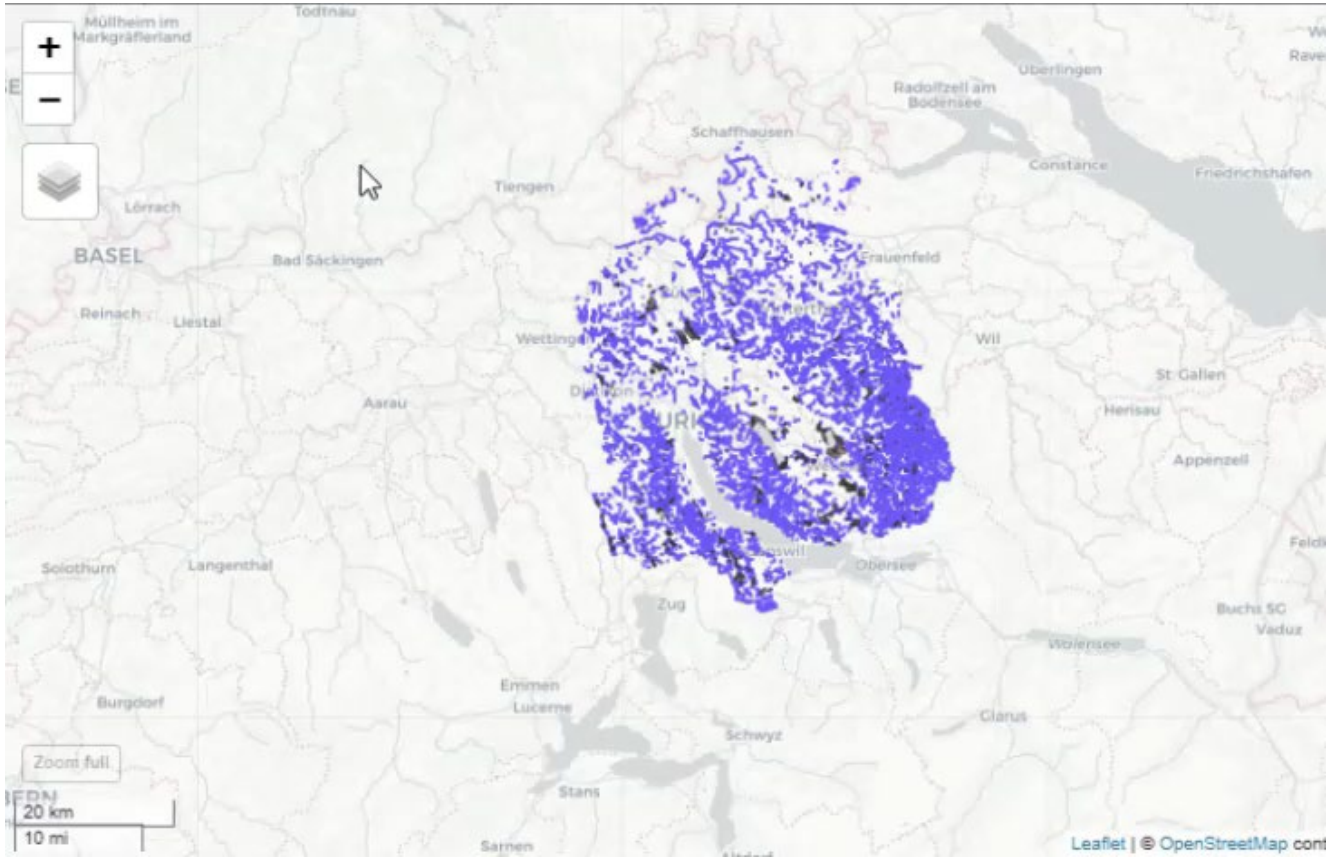
```r
# GWR (Gewässerraum): condition ~ value
oekom_fg <- oekom_fg %>% mutate(GWR = case_when(BDK & BGS < 1 ~ 11,
                                                BDK & BGS >= 1 & BGS <= 5 ~ (6 * BGS) + 5,
                                                BDK & BGS > 5 ~ BGS + 30,
                                                !BDK & BGS < 2 ~ 11,
                                                !BDK & BGS >= 2 & BGS <= 15 ~ (2.5 * BGS) + 7,
                                                !BDK & Siedl & BGS > 15 ~ GSBREITE + 40,
                                                !BDK &! Siedl & BGS > 15 ~ BGS + 40))
```

GitLab

Project information

R 91%

Example layers



- Various datasets (> 50; 4 examples)
- Polygon, line and point geometries
- Overlapping / intersecting areas
- Various attributes (for filtering)

Visualisation with ***mapview*** package (leaflet)

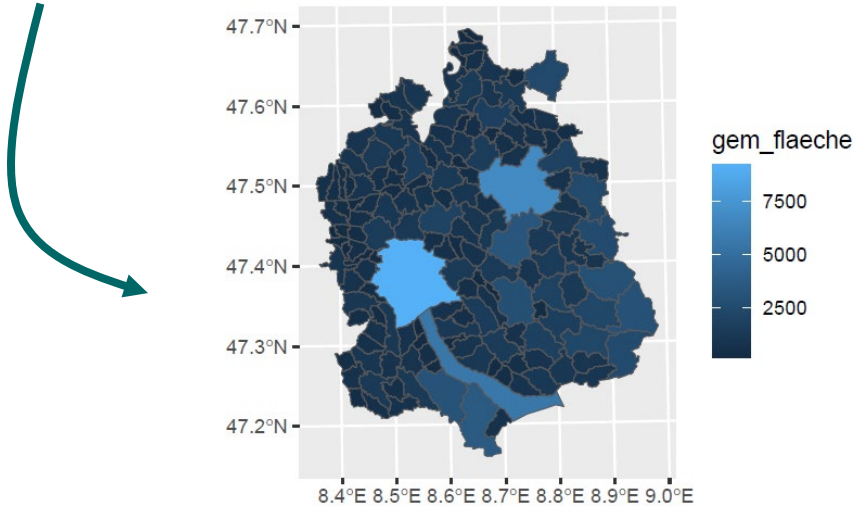
```
# leaflet html map
mapview(fg, col.regions="blue") +
  mapview(hm, col.regions="purple") +
  mapview(fm, col.regions="pink") +
  mapview(pfpl_f, col.regions="darkgreen")
```

sf package

- Implements the simple features open standard (OGC)
- Binds to GDAL, GEOS, PROJ (C++ libraries)
- It basically extends a table to spatial tables
- It covers basic (GIS) functionality and common data formats
- Simplifies spatial data analysis in R (sp → sf)
- Works with dplyr & ggplot2

	kantonsnummer	name	gem_flaeche	geom
1	20	Aadorf	1994	MULTIPOLYGON Z (((2709113 1...
2	19	Aarau	1234	MULTIPOLYGON Z (((2650939 1...
3	2	Aarberg	793	MULTIPOLYGON Z (((2588725 1...
4	19	Aarburg	441	MULTIPOLYGON Z (((2635520 1...
5	2	Aarwangen	990	MULTIPOLYGON Z (((2626666 1...
6	19	Abtwil	414	MULTIPOLYGON Z (((2668263 1...
7	22	Aclens	390	MULTIPOLYGON Z (((2530161 1...
8	21	Acquarossa	6178	MULTIPOLYGON Z (((2709308 1...

```r
library(dplyr)
library(sf)
library(ggplot2)

read_sf("swissBOUNDARIES3D_1_5_LV95_LN02.gpkg", "tlm_hoheitsgebiet") %>%
  filter(kantonsnummer==1) %>%
  ggplot() +
  geom_sf(aes(fill = gem_flaeche))
```



Processing pipeline

Main steps to generate the spatial basis for the ecological infrastructure planning

1. **Read** and prepare individual layers (n > 50)

```
lwg1 <- st_read(dsn = "data.gdb", layer = "A13_01_Extensive_Wiesen") %>%
  st_union() %>% st_sf(source="Ext. Wiesen")
lwg2 <- st_read(dsn = "data.gdb", layer = "A13_02_Wenig_Intensive_Wiesen") %>%
  st_union() %>% st_sf(source="Wenig int. Wiesen")
lwg4 <- st_read(dsn = "data.gdb", layer = "A13_04_Extensive_Weiden") %>%
  st_union() %>% st_sf(source="Ext. Weiden")
```

2. Assigning some **attributes**

```
vg_t_betrieb <- fun_merge(list(lwg1, lwg2, lwg4)) %>%
  mutate(teilebene="Trockenlebensraum", oei_kategorie="VG", stossrichtung="Betrieb") %>%
  rename(geometry='.')
```

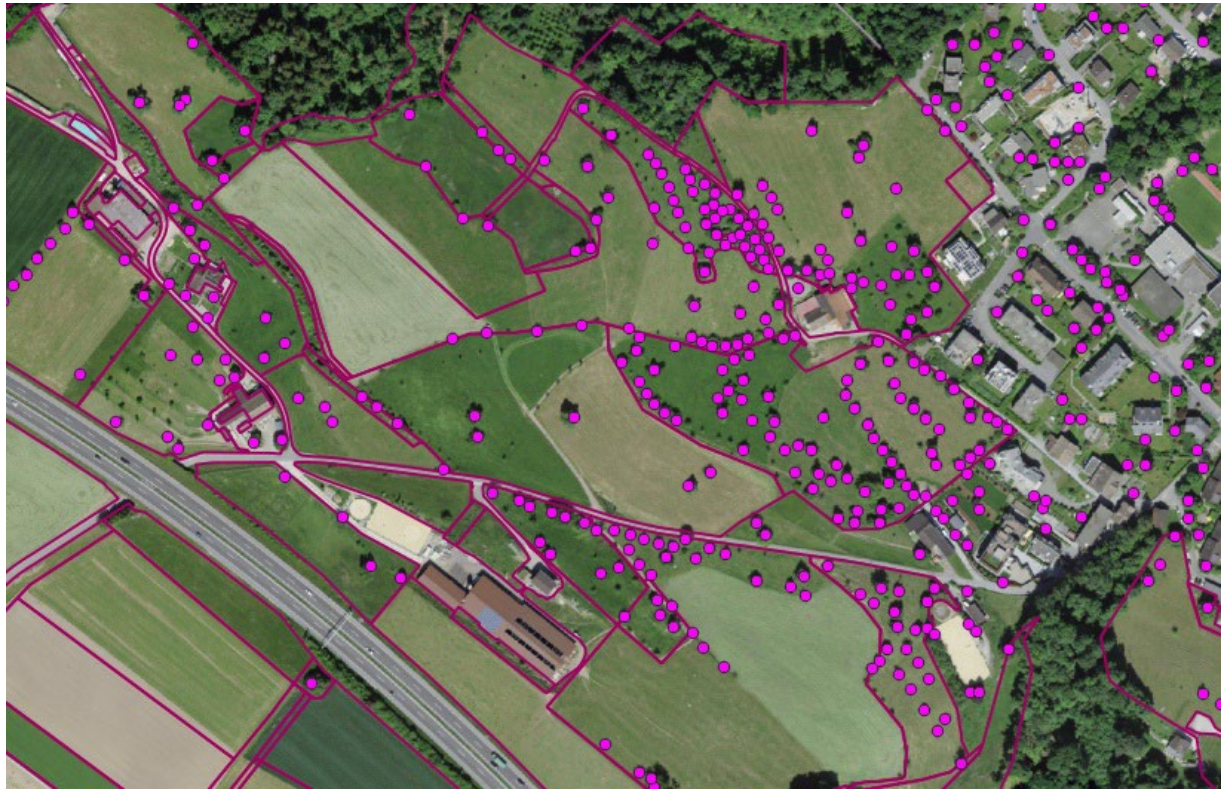
3. **Combining** all layers based on a defined hierarchy to generate non-overlapping polygons

```
all <- st_difference(kg_t_betrieb, st_union(all)) %>%
  rbind(all, .)
```

4. Calculation of area **statistics**, plots and maps (tidyverse)

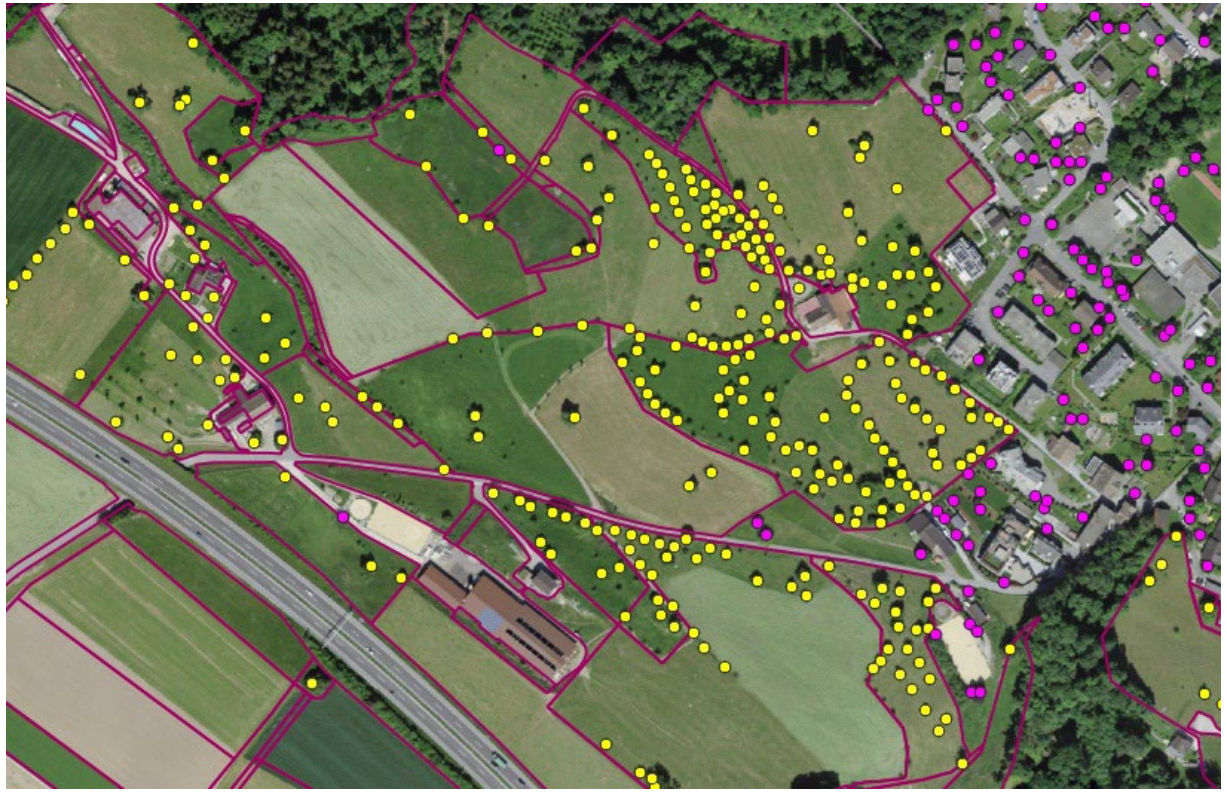
```
oei %>% st_drop_geometry() %>%
  group_by(teilebene, oei_kategorie, stossrichtung) %>%
  summarise(area=sum(area), ha=sum(ha)) %>%
  mutate(area=round(area), ha=round(ha))
```

Example: Orchards



Example: Orchards

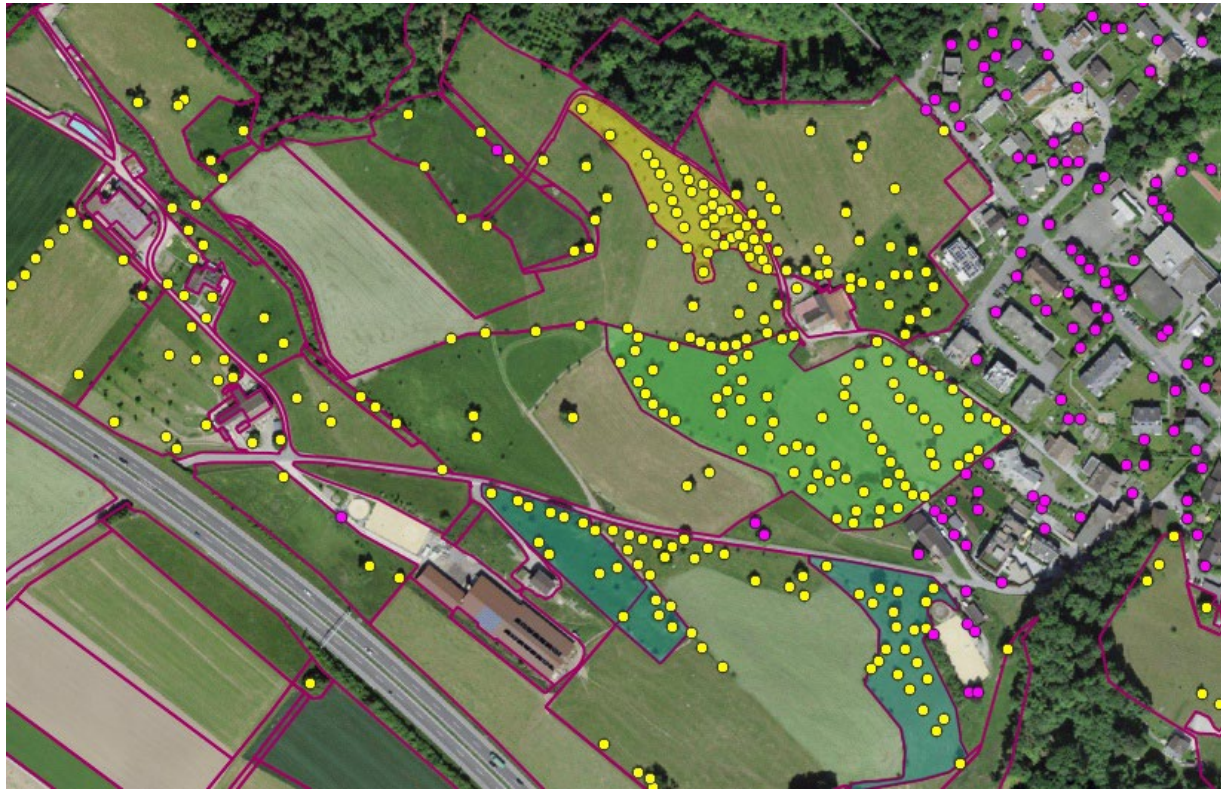

```r
# trees within agricultural area
trees <- st_intersection(trees, parcels)
```



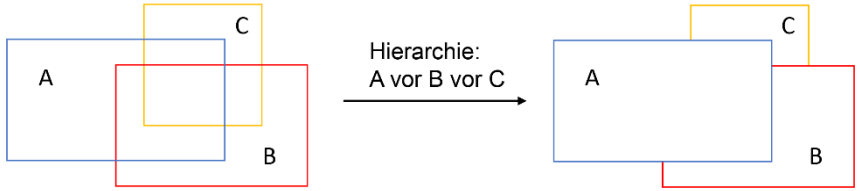
Example: Orchards


Bild: Joris Egger, Wikipedia

```r
# trees within agricultural area
trees <- st_intersection(trees, parcels)

# count trees per parcel
count_eb <- trees %>% group_by(GIS_NR) %>%
  summarise(nTrees=n(), .groups='drop') %>%
  as.data.frame()

# join
lwn <- left_join(lwn, select(count_eb, GIS_NR, nEB), by="GIS_NR")

# calculate density of trees per ha
lwn$area <- as.numeric(st_area(lwn))
lwn$DichteEB <- lwn$nEB/lwn$area*10000

# filter by density and agricultural use
lwn20baeume <- filter(lwn, DichteEB >=min_density &
                      DichteEB<=max_density) %>%
  filter(BLW_NR %in% c('0611','0612','0613',
                       '0621','0622','0623',
                       '0694','0697','0698',
                       '0616','0617','0693',
                       '0921','0702','0703',
                       '0704','0731','0730'))
```



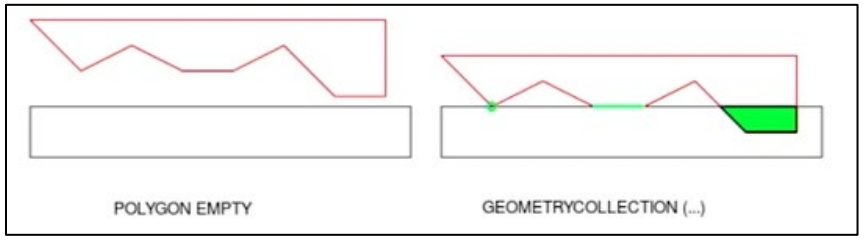
Tricky stuff



Problems occurred when mixing **different data formats** (GDB, SHP, GPKG), performing geometric operations on **complex geometries** and implementing **advanced functions**

What helped:

- st_collection_extract (e.g. get back to “POLYGON”)
- st_cast (e.g. to get back to simple geometry types)
- st_make_valid (to fix geometry issues; topology exceptions)
- st_drop_geometry (improve performance for non-spatial stuff)
- …



Edzer Pebesma (https://www.youtube.com/watch?v=yhpkx_xO-LE&t=1092s)

Collaboration


```r
library(sf)
library(mapview)
library(leaflet)
library(htmlwidgets)
library(dplyr)

# load data
al_kg <- st_read(dsn = "data/data.gdb", layer = "A03_05_amphibLaichgebiet_KG")
al_vg <- st_read(dsn = "data/data.gdb", layer = "A03_05_amphibLaichgebiet_VG")

# build map

al_map <- mapview(al_kg, col.regions="purple", layer.name="AL_KG") +
  mapview(al_vg, col.regions="pink", layer.name="AL_VG")

# add WMS layer
al_map <- al_map@map %>%
  addWMSTiles(group="Swissimage",
              baseUrl="https://wms.geo.admin.ch", layers = "ch.swisstopo.swissimage",
              options = WMSTileOptions(format = "image/png", transparent = TRUE)) %>%
  addWMSTiles(group="Waldareal",
              baseUrl = "http://wms.zh.ch/WaldarealzHWMS",layers = "WaldarealzHWMS",
              options = WMSTileOptions(format = "image/png", transparent = TRUE)) %>%
  mapview:::mapViewLayersControl(names = c("Swissimage","Waldareal")) %>%
  hideGroup(c("Swissimage","Waldareal")) %>%
  setView(8.65, 47.4 , zoom = 10)

# write self-contained html (folder is not removed, but html works as single file)
saveWidget(al_map, "D:/al_map.html", selfcontained=T)
```

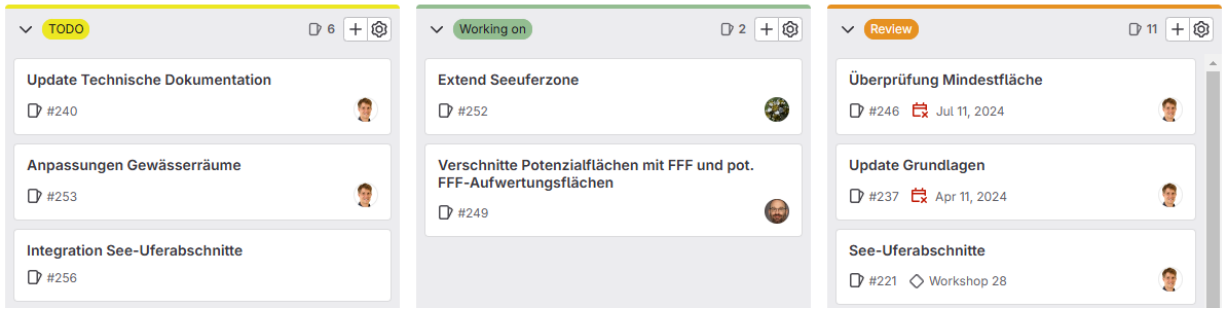
GitLab

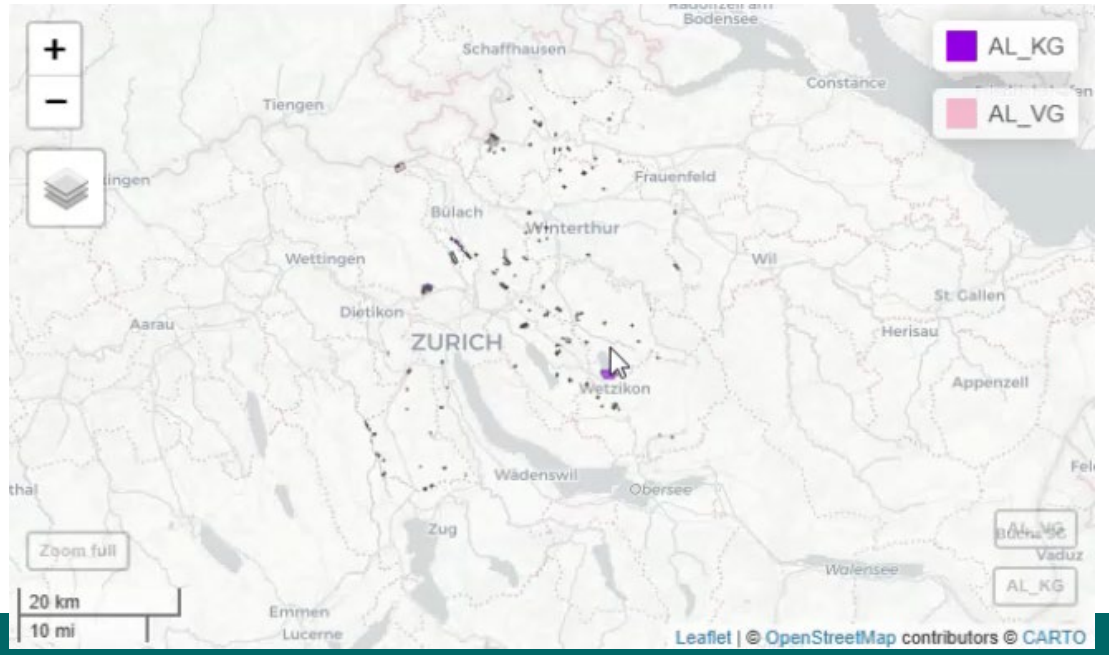
Project information

318 Commits

oekologische-infrastruktur-zh / Issues

Open 30 Closed 226 All 256





Conclusion

- Fully automated & well-documented workflow for processing various geospatial data for ecological infrastructure planning, using mainly R (and a bit of ArcPy)
- R has become powerful for reproducible spatial data analysis (package evolution, community)
- The suitability of using R for spatial data analysis depends on several factors (complexity, performance, maintenance, experience, etc.)
- Don’t mix data formats, use open standards (e.g. GPKG)
- Working with lots of vector data easily becomes messy

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Thank you for your attention

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