Kick-Off Meeting

Urban Green Space Mapping Through Remote Sensing for Frankfurt/Main, Germany

Omdena

Omdena Project Types:

- Local Chapter Challenges
- AI Innovation Challenges
- Top Talent Projects

The mission of Omdena Local Chapters is to run open-source AI projects to solve challenges faced by local communities

- Chapters in 50+ countries
- Starting 10+ projects per month
- 80+ collaborators per project

This is the first project of the Frankfurt Chapter

Urban Greenery

Why map urban greenery – 'cause you can plan and monitor it then

SOTA of urban vegetation mapping:
Ground observation of the entire urban greenery or purchasing imagery of high-resolution satellites is a costly affair. Thus, methods based on low-resolution missions such as Sentinel-2 are developed – often town-specific. Deep learning architectures can be thus trained to map individual trees for highly controlled image inputs. Benchmark studies so far are dominated by computationally expensive solutions – hindering their adoption.

SOTA of computer vision:
Newly developed deep learning solutions claim to both be computationally more efficient and surpass detection limits. For example, in 2024 variations of the structured space state sequence model 'mamba' were adapted to remote sensing. Can it or alternative approaches from 2024 push both computational efficiency and detection limit?

The mission statement:
Which services to monitor and plan urban greenery could we offer Frankfurt/Main and other cities? How reliable and precise while computational efficient can we get?

Outcome of benchmarked methods

TABLE I: Classification results of Augsburg dataset in terms of F-1 score where κ = Kappa index, OA = Overall Accuracy, AA = Average Accuracy, respectively.

Class	HybridSN	ResNet	iFormer	Efficientformer	CoAtNet	SGU-MLP
Forest	0.88	0.83	0.91	0.88	0.85	**0.94**
Residential	0.89	0.83	0.89	0.9	0.87	**0.95**
Industrial	0.43	0.15	0.35	0.4	0.22	**0.63**
Low Plants	0.87	0.88	0.88	0.88	**0.98**	0.96
Allotment	0.13	0.1	0.13	0.11	0.09	**0.36**
Commercial	0.04	0.05	0.1	0.11	0.16	**0.28**
Water	0.35	0.19	0.21	0.25	0.19	**0.52**
OA×100	82.28	79.07	82.82	82.72	81.32	**91.82**
AA×100	55.76	43.57	52.96	52.81	49.9	**66.79**
κ×100	74.85	69.34	75.37	75.24	73.12	**88.22**

TABLE II: Classification results of Berlin dataset in terms of F-1 score where κ = Kappa index, OA = Overall Accuracy, AA = Average Accuracy, respectively.

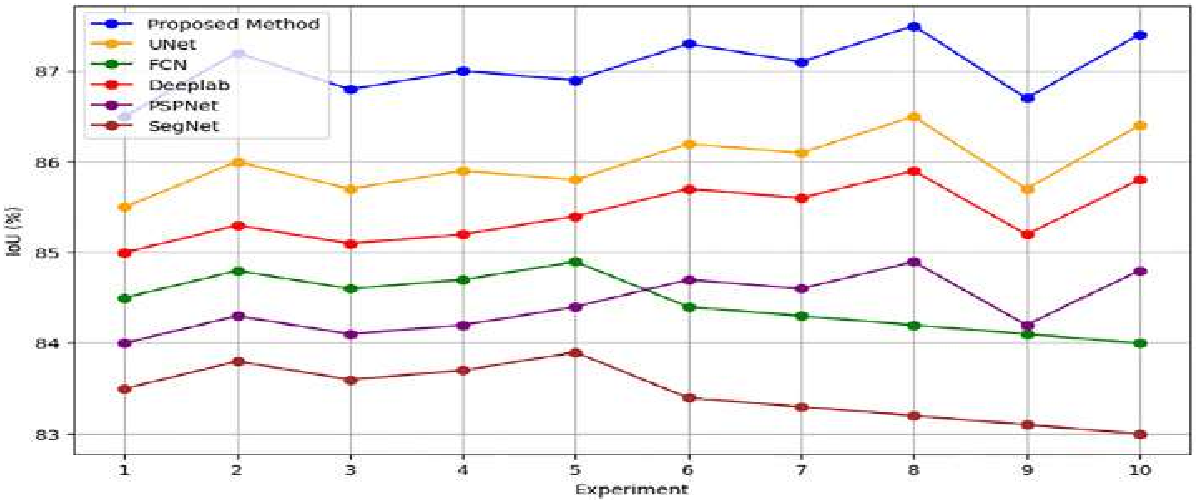
Class	HybridSN	ResNet	iFormer	Efficientformer	CoAtNet	SGUMLP
Forest	0.71	0.64	0.69	**0.73**	0.65	**0.73**
Residential	0.8	0.81	**0.82**	0.81	0.76	**0.82**
Industrial	**0.49**	0.39	0.35	0.32	0.32	0.41
Low Plants	0.59	0.35	0.72	0.7	0.59	**0.72**
Soil	0.65	0.72	0.7	0.67	**0.75**	0.67
Allotment	0.44	0.28	0.34	0.29	0.3	**0.46**
Commercial	**0.45**	0.25	0.29	0.24	0.29	0.27
Water	**0.65**	0.53	0.49	0.38	0.28	0.48
OA×100	66.81	63.7	68.6	68.17	63.14	**70.79**
AA×100	62.67	58.23	62.84	60.05	60.53	**66.26**
κ×100	55.84	47.61	55.28	54.32	49.21	**58.06**

TABLE III: Classification results of Houston dataset in terms of F-1 score where κ = Kappa index, OA = Overall Accuracy, AA = Average Accuracy, respectively.

Class	HybridSN	ResNet	iFormer	Efficientformer	CoAtNet	SGUMLP
Healthy Grass	0.85	0.88	0.86	0.89	**0.9**	0.89
Stressed Grass	0.84	**0.9**	0.87	0.87	0.88	0.89
Synthetic Grass	0.84	0.78	0.5	0.58	0.72	**0.97**
Tree	0.87	0.89	0.92	0.91	0.93	**0.94**
Soil	0.96	0.94	0.93	0.95	0.85	**0.99**
Water	**0.73**	0.71	0.29	0.39	0.25	0.35
Residential	0.69	0.72	0.68	0.6	0.79	**0.81**
Commercial	0.69	0.39	0.68	0.56	0.6	**0.83**
Road	0.7	0.57	0.75	0.77	0.82	**0.85**
Highway	0.58	0.52	0.45	0.54	0.54	**0.89**
Railway	0.7	0.54	0.67	0.57	0.67	**0.82**
Parking Lot1	0.74	0.42	0.48	0.71	0.55	**0.96**
Parking Lot2	**0.94**	0.61	0.72	0.78	0.58	0.9
Tennis Court	0.84	0.77	0.74	0.73	0.56	**0.99**
Running Track	0.64	0.82	0.83	0.61	0.92	**0.95**
OA×100	75.62	68.16	71.03	71.66	72.67	**87.91**
AA×100	76.44	71.42	72.86	70.69	75.62	**89.33**
κ×100	73.59	65.49	68.71	69.25	70.56	**86.91**

https://arxiv.org/pdf/2308.05235

Deep learning and generative adversarial networks Vs Traditional methods (ISPRS Potsdam IoU %)



https://pmc.ncbi.nlm.nih.gov/articles/PMC11257302/

Your learning outcome of this project

(1) Conquer new topics in Data Science and Deep Learning through **collaboration** – a systematic way of entering new knowledge fields such as:

- spatial data
- computer vision
- U-net/mamba/SGU-MLP/etc

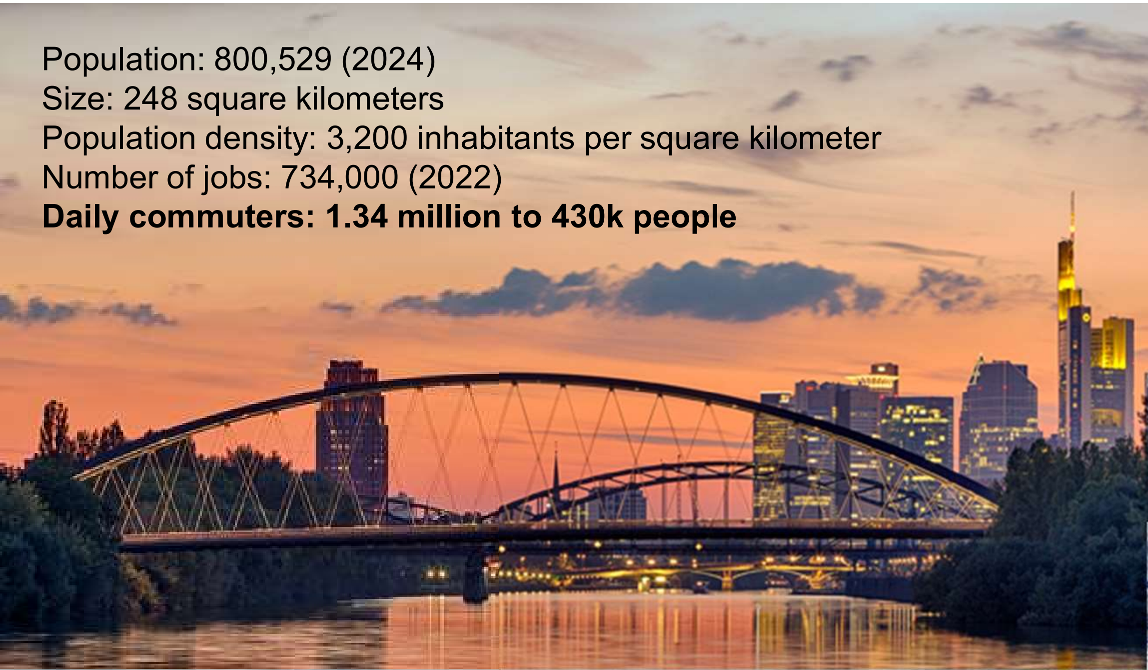
(2) Listen to talks of local stakeholders in urban vegetation planning

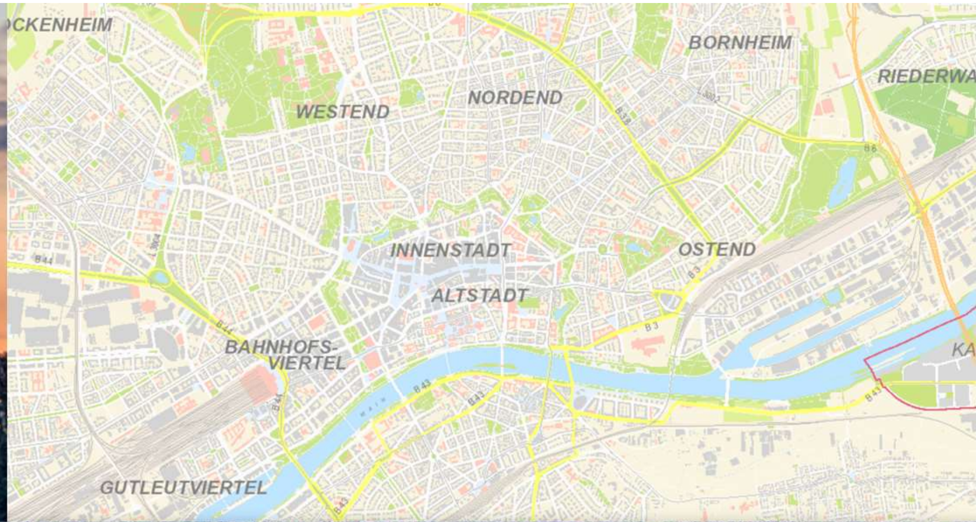
(3) Get inspiration for what is technically possible in urban planning enhanced through environmental sensing and AI

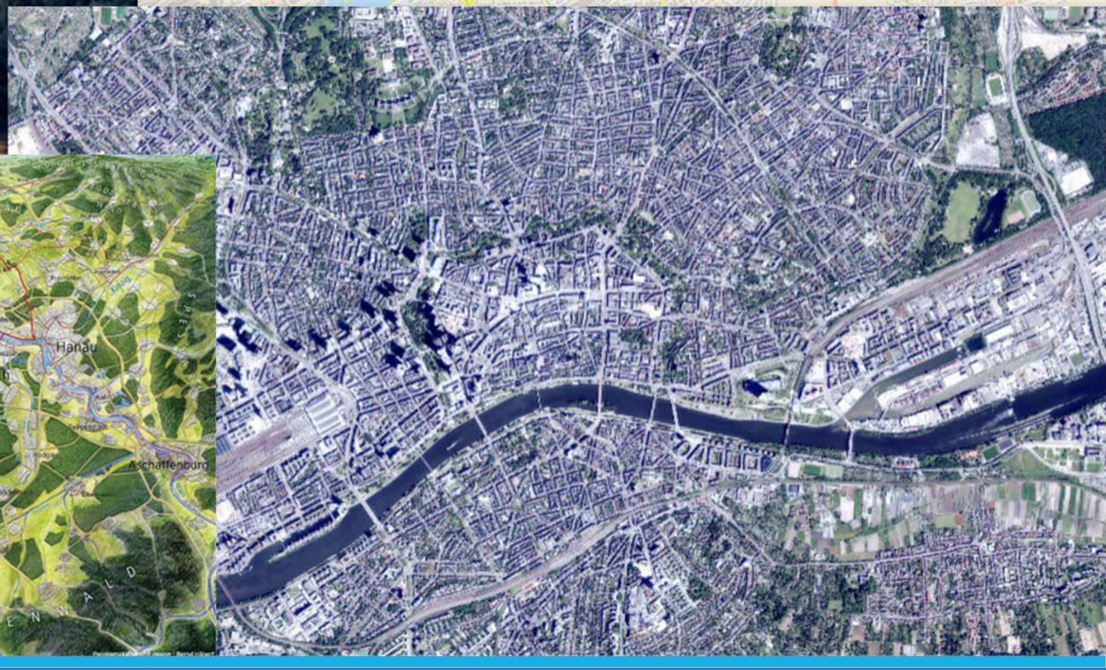
The Project Team

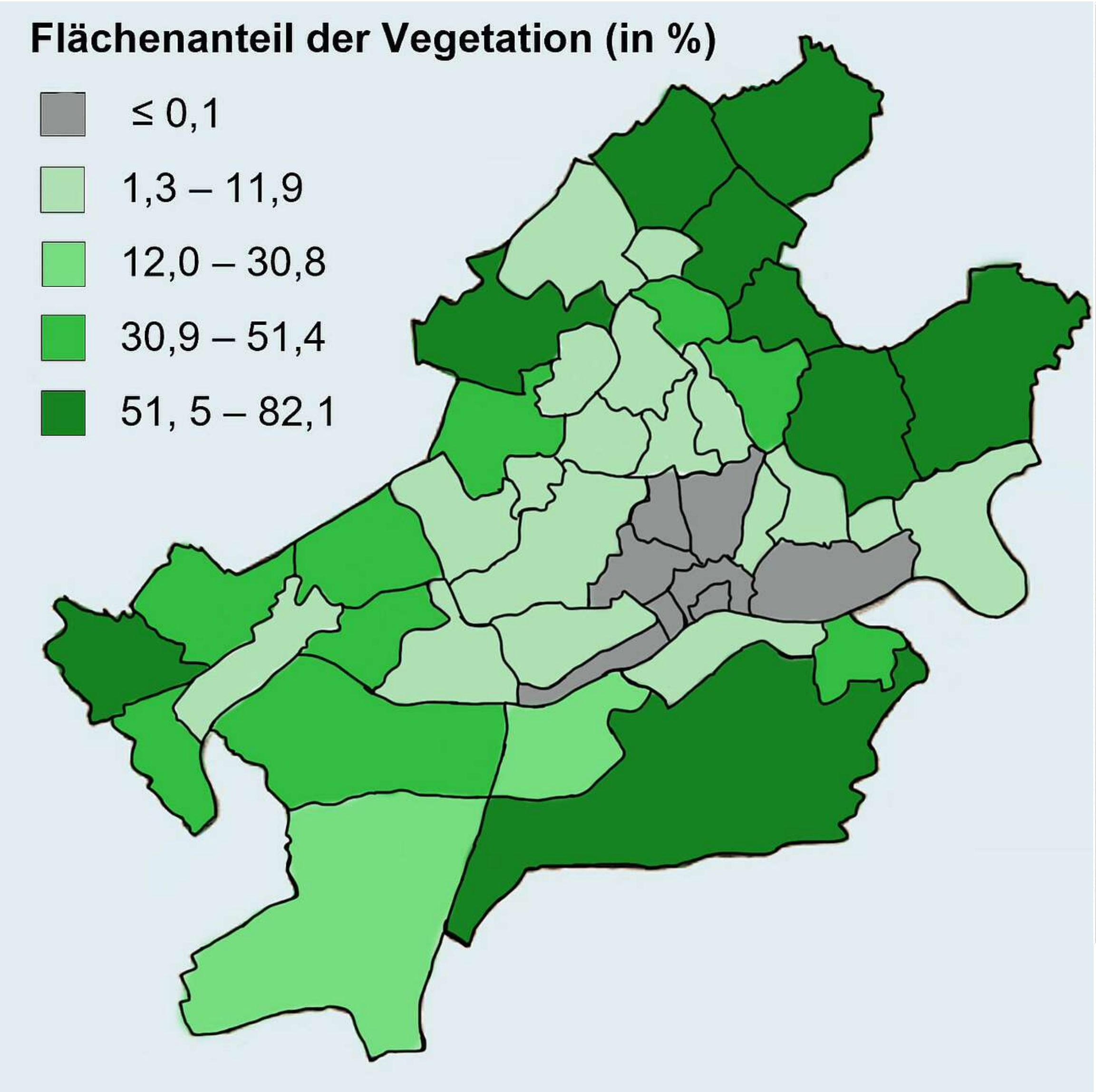
The location and data

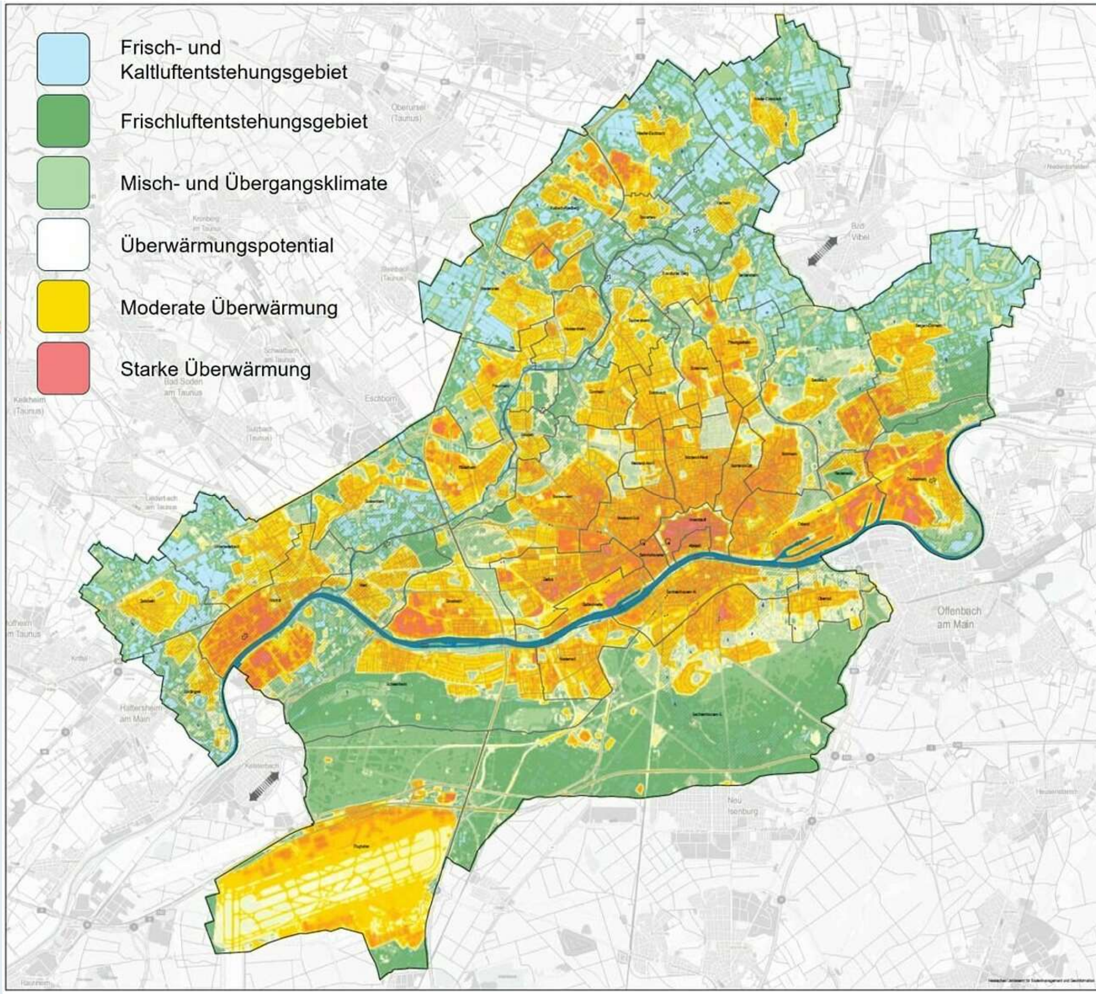
Population: 800,529 (2024)
Size: 248 square kilometers
Population density: 3,200 inhabitants per square kilometer
Number of jobs: 734,000 (2022)
Daily commuters: 1.34 million to 430k people





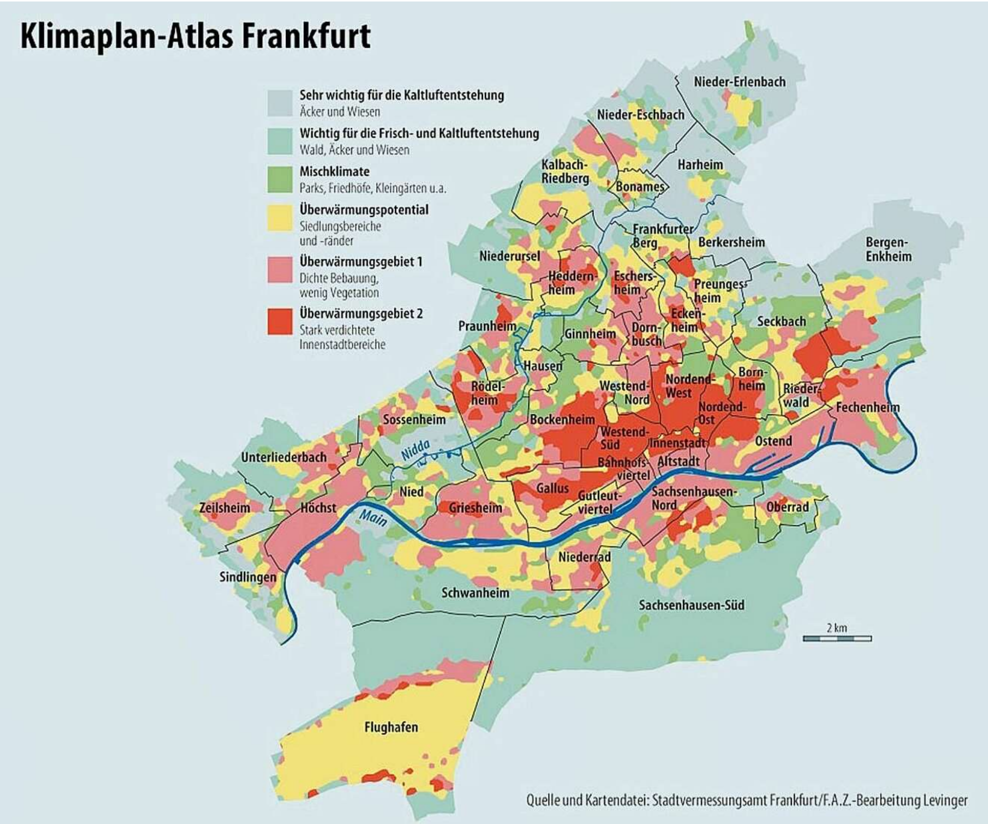


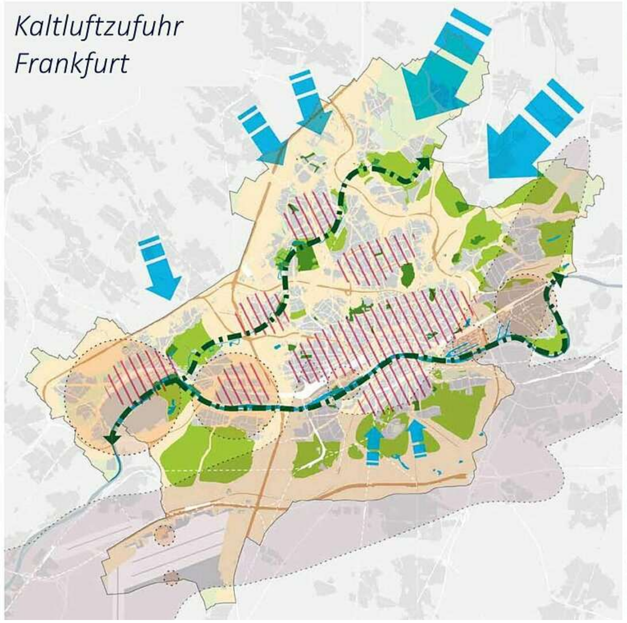


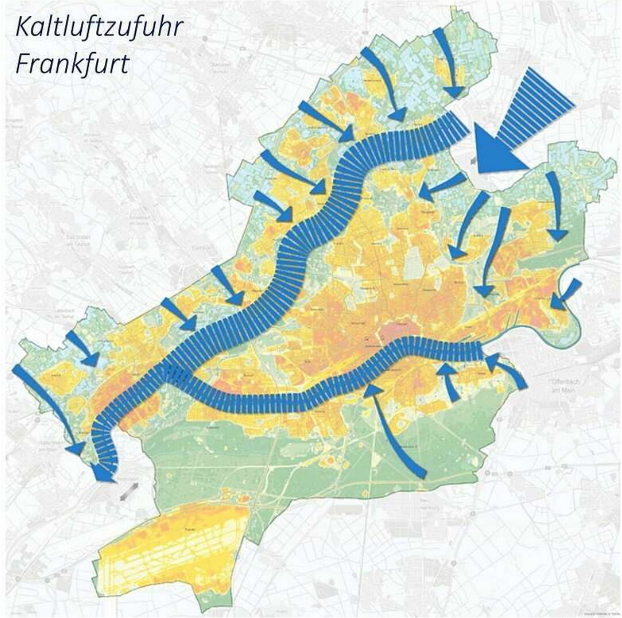


Share vegetation space: 40 %
Share building space: 40 %
Number of city trees: ~200‘000

Besides vegetation wind management shapes urban heat

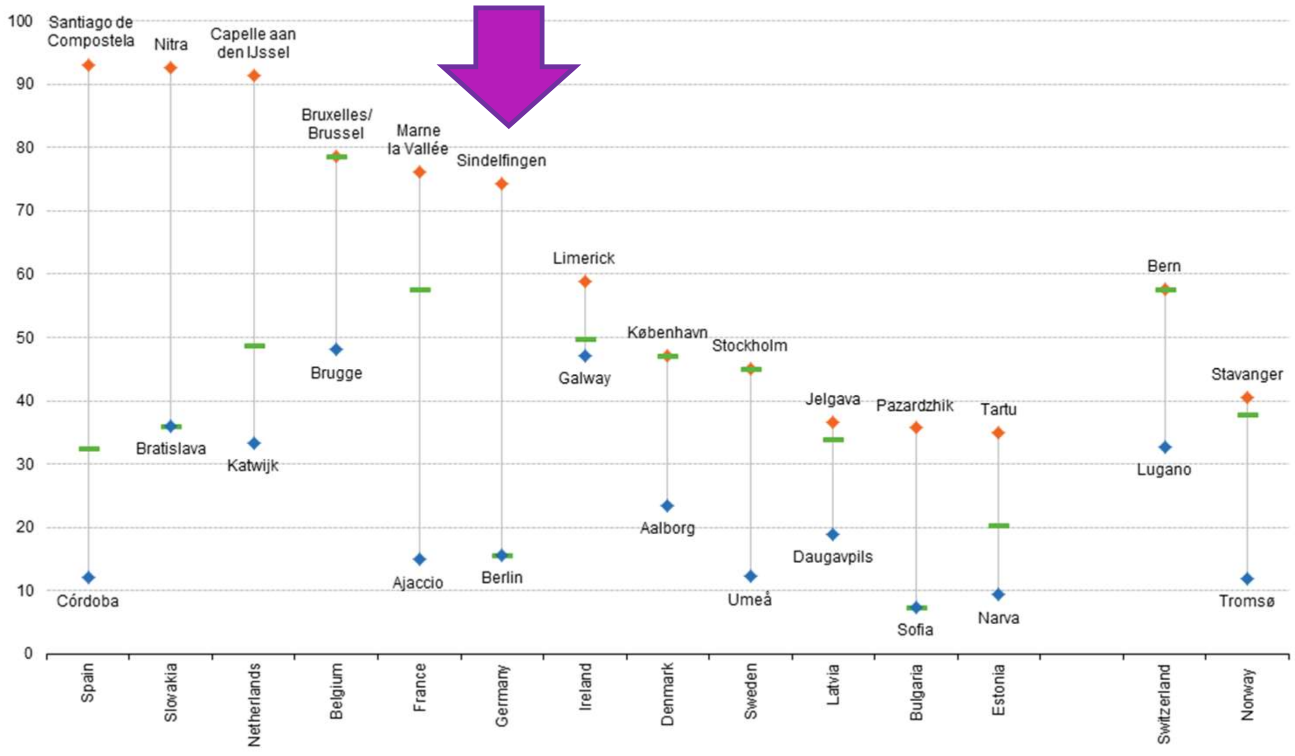






While Frankfurt's skyline is representative of modern global cities, its **topographical variance**—with hills, rivers, and surrounding forests—may be more pronounced than in many other urban centers.

Fun facts about Frankfurt…



- Frankfurt/Main is a leading commuter hub
- The RheinMain region contributes 5-6% of Germany‘s GDP
- It is home to the European Central Bank
- Its airport handles: 6-7% of total EU passenger traffic, 4-5% of total EU flight movements, 12-15% of the EU's total cargo volume

As a developed city Frankfurt monitors its green extensively…

Frankfurt has approximately 58% of its space compromised by green space (including e.g. private gardens) – that is below the German average (86%) but well above the European average (42%)

Public parks make up only 4.3% of the city space

City-wide initiatives for green monitoring or more green:

- Grünflächenamt
- Umweltamt Frankfurt
- Klima-Büro Frankfurt
- AI Frankfurt
- Frankfurt Green City
- Frankfurt frischt auf
- Altes Neuland Frankfurt

BUT

Green space is not evenly distributed over the town

Only 1.3% of the town budget (~4 billion Euros annually) are spent on environmental concerns – 1/5th of that is spent on garbage disposal

Besides Sentinel-2 imagery, this project is based on this data:

Web-view of Frankfurt city data: *https://geoportal.frankfurt.de/karte/*

HR air photos of Frankfurt as tiff (summer of 2023): *https://www.govdata.de/suche/daten/atkis-dop-20*

HR air photos of Frankfurt as WMS (summer of 2023):
https://www.geoportal.hessen.de/mapbender/php/mod_showMetadata.php?resource=layer&languageCode=de&id=54451

Inventory (with species name) of urban city trees: *https://data.europa.eu/data/datasets/73c5a6b3-c033-4dad-bb7d-8783427dd233?locale=en*

Open Street Map Frankfurt: *https://www.openstreetmap.org/relation/62400#map=15/50.11209/8.67581*

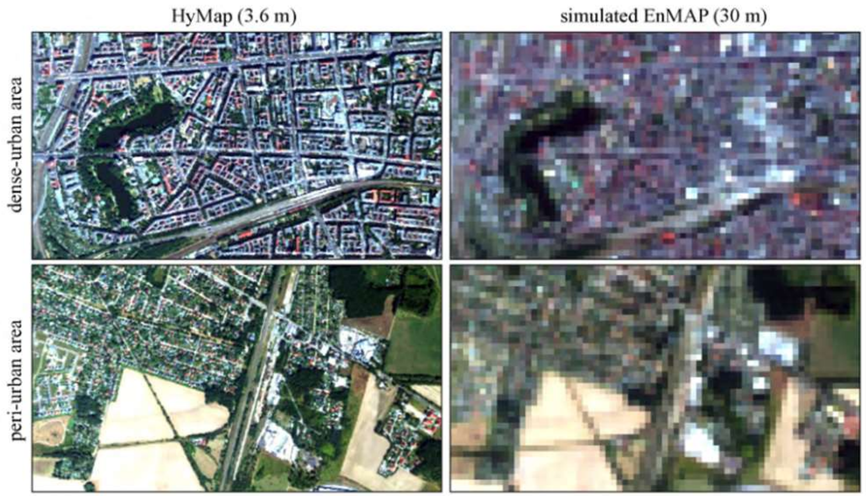
Biotop Kartierung Frankfurt am Main: *https://offenedaten.frankfurt.de/dataset/biotopkartierung-2021-wfs-und-wms-frankfurt-am-main*

Rain-runoff map Frankfurt am Main: *https://offenedaten.frankfurt.de/dataset/starkregengefahrenkarten-wms-2021-frankfurt-am-main*

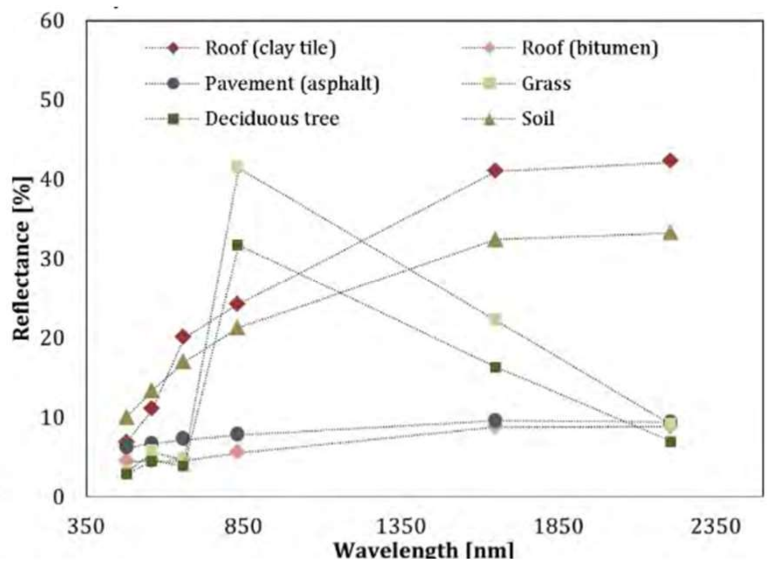
For WMS/WFS data, you can access them through python or download the GUI freeware QGIS

Methodology and project plan

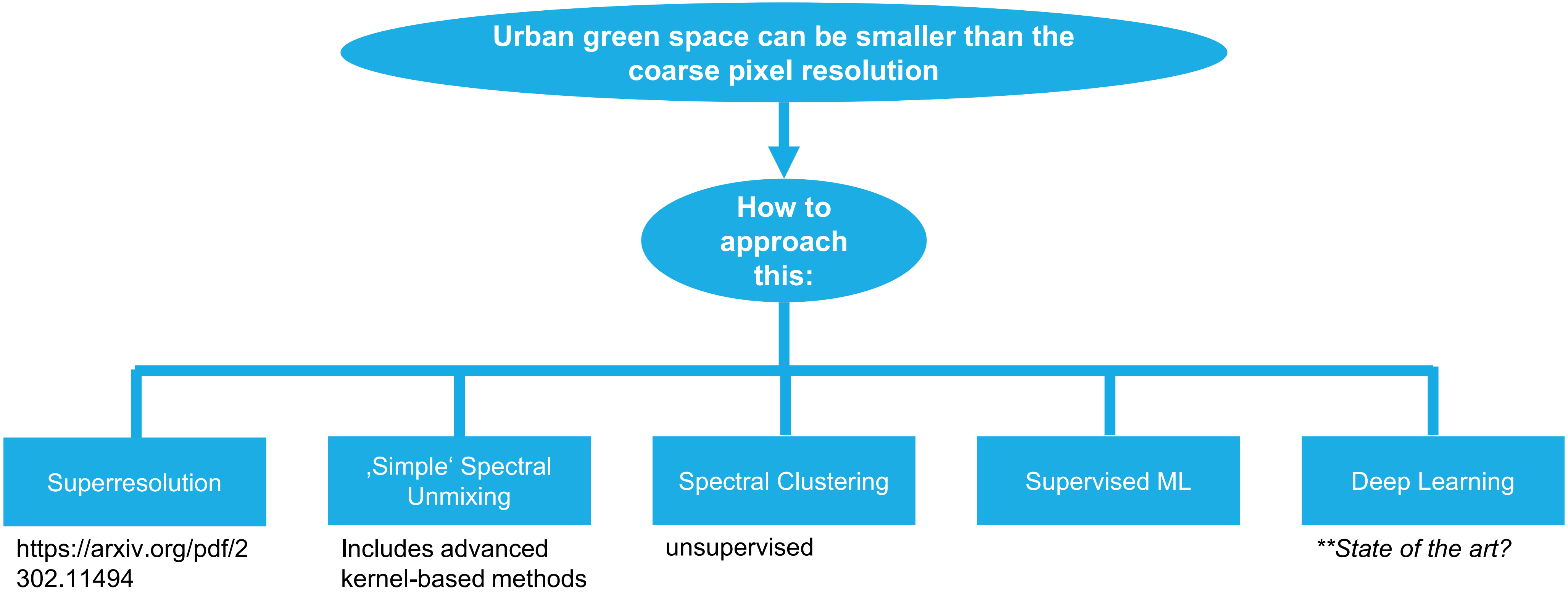
What resolution does to your remote image…



Landsat ETM+ (30 m; 6 spectral bands)



The Problem Statement again…



Project Plan – Weekwise

<u>Preparatory Phase</u>

Training in geospatial library usage → Ground truth generation

-> Participation in the preparatory phase is mandatory! Final access to data for deep learning is only granted to people who participated in it

<u>Mapping Phase</u>

Team	Weeks 3-5	Weeks 6-8
A	Kernal-based MESMA	Clustering to unmix pixels
B	U-net	U-net
C	U-net and Input amplification	U-net and Input amplification
D	DL Method of Choice	DL Method of Choice
E	SGU-MLP	SGU-MLP
F	Mamba I	Mamba I
G	Mamba II	Mamba II
H	****Analysis of Temperature, Vegetation, Topography****	****Analysis of Temperature, Vegetation, Topography****

The preparatory phase

Challenge: append map of urban vegetation in Open Street Map with information from 20cm * 20cm resolution air photographs

Use method described here:

https://www.mdpi.com/2220-9964/10/4/251

https://heidata.uni-heidelberg.de/dataset.xhtml;jsessionid=a64fd55022cde3237c69553fbfb4?persistentId=doi%3A10.11588%2Fdata%2FUYSAA5&version=&q=&fileTypeGroupFacet=&fileAccess=Public&fileSortField=size&tagPresort=false

https://mirror.netcologne.de/CCC/events/sotm/2019/h264-hd/sotm2019-1899-eng-Assessing_the_Completeness_of_Urban_Green_Spaces_in_OpenStreetMap_hd.mp4

https://senseable.mit.edu/treepedia

Sample changes and visually expect them.

The preparatory phase - teams

Week 1:
Each participant can join 1 out of 8 teams – each team covers a different geographic area
The teams practice together the use of geospatial libraries in python

Week 2:
Code to append Google Street Maps will be provided
The teams can test and improve the code for their region
The teams will visually inspect samples of their results
****Additionally, vegetation will be compared with Biotop Map*

Some reading for the Mapping Phase

MESMA and Clustering:

- https://zhouyuanzxcv.github.io/files/papers/Zhou%20et%20al_2020_Unmixing%20urban%20hyperspectral%20imagery%20using%20probability%20distributions%20to%20represent%20endmember%20variability.pdf
- https://www.cedric-richard.fr/Articles/chen2011novel.pdf
- https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0124608
- https://arxiv.org/pdf/2001.07307
- https://www.researchgate.net/profile/Rob-Heylen-2/publication/264564339_A_Review_of_Nonlinear_Hyperspectral_Unmixing_Methods/links/53f485700cf2888a7491048d/A-Review-of-Nonlinear-Hyperspectral-Unmixing-Methods.pdf
- https://www.mdpi.com/2072-4292/16/15/2851

U-net:

- https://sh-tsang.medium.com/review-recurrent-u-net-for-resource-constrained-segmentation-a50c769e2b50
- https://www.researchgate.net/profile/Tony-Boston/publication/384330477_Deep_learning_convolutional_neural_networks_for_Landsat-derived_land_cover_mapping/links/66f4bb89906bca2ac3c9bc17/Deep-learning-convolutional-neural-networks-for-Landsat-derived-land-cover-mapping.pdf

Input Amplification:

- https://www.sciencedirect.com/science/article/pii/S2352938524000168

SGU-MLP:

- https://ieeexplore.ieee.org/document/10399888

Mamba:

- https://github.com/ReaFly/Awesome-Vision-Mamba
- https://www.mdpi.com/2072-4292/16/19/3622

Inspiration for the vegetation/temperature/topography team

- Estimate biomass: https://news.ku.dk/all_news/2023/10/new-study-finds-hidden-trees-across-europe-a-billion-tons-of-biomass-is-overlooked-today/
- Sponge city: https://ascelibrary.org/doi/full/10.1061/JSWBAY.0000862
- Vegetation against heat islands: https://www.kth.se/en/seed/forskning/alg/pagaende-forskningsprojekt/stockholm-heat-1.1092946
- Monitoring trees: https://datasmart.hks.harvard.edu/fighting-climate-change-data-driven-urban-forestry
- Public Tree Map App: https://www.hackforla.org/projects/public-tree-map.html
- Biodiversity Mapping: https://environmentalsolutions.mit.edu/news/artificial-intelligence-for-urban-biodiversity-mapping/

From Dec 8th, 2024

Duration

~ 8 weeks

Planned Output: a Medium blog post with main author „Local Chapter Frankfurt“ and links to all contributors

See here for an example: https://www.omdena.com/blog/image-analysis-fires

Member Rules & Guidelines

- English is the language to be used for any communication about the project (Slack,mail,...)
- Only contributions to slack channels count as contributions – private messages do not

- The preferred coding environment are colabs/kaggle notebooks
- You can create shared git projects with your team instead if you all agree on it
- IMPORTANT: always track your use of computational resources!!!

- It seems likely that the primary coding language is python
- if you want to use R or Java, you can use python libraries interfacing R/Java with python, such as e.g. rpy2 or Py4J
- otherwise discuss in your team to use alternative coding language

Project Management Tools that could be used within teams

Trello Boards for keeping track of ToDos?

https://trello.com/

Zotero for keeping track of research?

https://www.zotero.org/

Milanote and Obsidian for keeping track of team ideas?

https://milanote.com/

https://obsidian.md/

GitHub Projects and ZenHub for keeping track of coding?

https://www.zenhub.com/

OMDENA'S CORE VALUES

Omdena's most basic principle is the desire to learn and grow. **Through curiosity, a person constantly asks questions and seeks answers.**

Curiosity

Compassion

Every member is motivated to help others, especially the less fortunate. **With compassion we ask ourselves "how can we help?"**

Collaboration among diverse talents allows us to bridge gaps in understanding between different mindsets, share knowledge, and unite people and values. It also helps harness crowd wisdom, diversity and inclusion. **Through collaboration, we collectively build ethical solutions.**

Collaboration

Consciousness

Because there are so many divisions in this world, we need to understand that deep down we are all one, we live on one planet and our future is interconnected. **Through consciousness, we think and act collectively as one.**

Projects/Labs to follow

- MIT Senseable City Lab: Founded the Treepedia “Green View Index” Project, Dust Tracker, and more (blending local/ground/IoT and remote sensing data and approaches)
- MIT Sustainable Urbanization Lab: Putting urban sustainable design into context with social, policy, and economics research.
- Microsoft Planetary Computer: Similar to Google Earth Engine
- US Forest Service’s Urban Forestry Programs
- https://www.lup-umwelt.de/en/urbangreeneye/
- https://urbancanopy.io/about
- https://www.isprs.org/education/benchmarks/UrbanSemLab/semantic-labeling.aspx
- https://spacenet.ai/challenges/
- https://opportunities.spaceinafrica.com/register-for-the-mjini-hackathon/

Some more reading

Reviews from 2021 about Urban Green Space Mapping:
- https://www.sciencedirect.com/science/article/abs/pii/S1618866720307639
- https://www.mdpi.com/2072-4292/14/4/1031

Example of limit of green space mapping in urban areas
- https://thilowellmann.de/wp/wp-content/uploads/2018/11/HaaseJ%C3%A4nickeWellmann_FrontBackyardGreen_AcceptedManuscript.pdf

Vegetation indices
- https://www.sciencedirect.com/science/article/pii/S1470160X24011026
- https://journals.vilniustech.lt/index.php/GAC/article/download/18724/12263
- https://d1wqtxts1xzle7.cloudfront.net/84839310/j.rse.2012.10.02920220425-1-1ibpxp0-libre.pdf?1650876954=&response-content-disposition=inline%3B+filename%3DQuantifying_tree_mortality_in_a_mixed_sp.pdf&Expires=1729243529&Signature=RKZZAnCubdlNggjklkofw4~EztKwSyoWCiYtaeMO~OHnz8iwP-quks3~ZDXYR50UJUp9507EMezA8p20R2GhcZemKNKA4K27m4AjPsMEcRMGf34r-uC2uuDIHEzah5tu-T3Do3SHeAmteNxjn8dQ0JekBNnAquSQx2ASk9d3NXcTRteWWCDoBsgHpjksf5~0~YTE5RB~-jlQeG33hr6-IVQWBdpuQG5~~rWnOaUG~Qz9d3tsdLe8ky8pC7ZcDXFyKW-J0hdC08HRIKr1A535R6BOEKEdvx~VXqNC63eUVY8TsflEFyTOJBpFg3GB8yI3gWTK3oxApTEwSeBTnTjL5w__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

https://towardsdatascience.com/best-libraries-for-geospatial-data-visualisation-in-python-d23834173b35
https://python.plainenglish.io/unlocking-the-power-of-python-top-gis-and-remote-sensing-libraries-for-data-analysis-bb968e3139e9
https://www.coursera.org/learn/spatial-data-science?
https://www.coursera.org/learn/remote-sensing
https://www.esri.com/training/mooc/
https://eo4society.esa.int/wp-content/uploads/2021/02/D3T2b_LTC2015_vanderLinden.pdf
https://sentiwiki.copernicus.eu/web/s2-mission
https://github.com/satellite-image-deep-learning/techniques
https://www.youtube.com/watch?v=q_gdOcpWmPo
https://www.sciencedirect.com/science/article/abs/pii/S0924271617303453
https://medium.com/sentinel-hub/multi-temporal-super-resolution-on-sentinel-2-imagery-6089c2b39ebc

Thank you everyone!
Keep in touch on Slack!