

High-Resolution Landsat-8 satellite images for human density prediction

Youcef Kacer

www.github.com/ykacer

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2 Landsat-8 imagery

- Earth Covering
- Image Georeferencement

3 Importing Data

- Image query
- Image bands

4 Importing labels

- Importing densities
- Categorize densities to Classification

5 Vegetation index extraction

- NDVI extraction
- NDVI evolution
- Data to Machine Learning

6 Supervised Classification

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- Population census is expensive using conventional methods
 - 180 millions euros in France ([officials,1999](#))
- How High-resolution satellites images could explain human density ?
- How to transform HR satellite images to explain human density ?

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- Total earth covering defined by (path,row) grid pattern and achieved every 16 days



Landsat-8 grid covering (path, row) for Virginia (USA)

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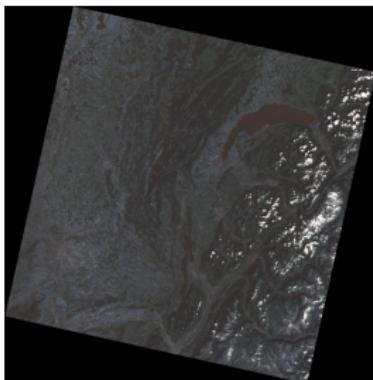
6 Supervised Classification

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- Landsat-8 images are georeferenced which means each pixel has (x,y) meter coordinates in a certain Projection Coordinates System (*ex : UTM, Lambert IV, Lambert 93, Web Mercator,...*)



Landsat-8 Eastern-France image
path=196, row=028
georeferenced in *UTM* system
(image containing city
Thonon-les-Bains)

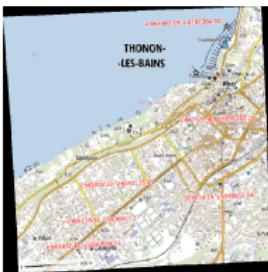
UTM corner coordinates (meters)

- upper-left (486202.777, 5958940.580)
- lower-left (486202.777, 5610657.403)
- upper-right (828135.467, 5958940.580)
- lower-right (828135.467, 5610657.403)
- center (657169.122, 5784798.992)

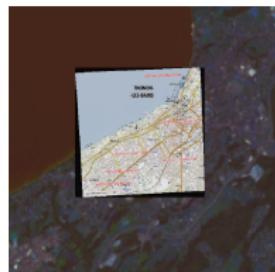
- Landsat-8 georeferencement can be checked comparing with another georeferenced source like *IGN* using a *SIG* (open source *QGIS*).



IGN image georeferenced in *Lambert 93* system



Then IGN image is transformed to be georeferenced in *UTM* system



Superposition of IGN and Landsat-8 images both georeferenced in *UTM* system

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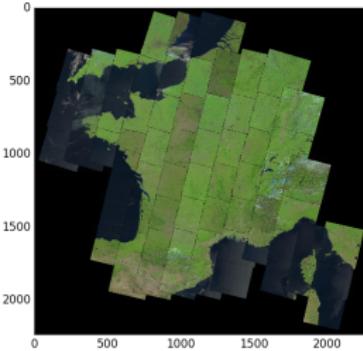
- Neural Network

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- Query images from *U.S geological Survey* website with criterias :
 - cloud covering $\leq 20\%$
 - day acquisition
 - between May, 2013 and September, 2013

Polygon selection on *USGS* website



68 resulting datasets georeferenced in
Web Mercator system

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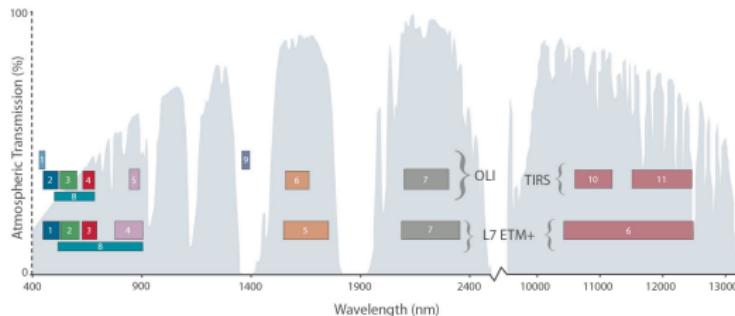
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- Landsat-8 dataset is composed of
 - 11 bands (OLI/TRS sensors) + 1 quality band (cloudyness of each pixel)
 - Possible combination of bands to extract information (bands 4 and 5 for vegetation presence)



Landsat-8 bands (OLI/TIRS sensors)

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- Take cities surfaces and densities from 2013 official census (INSEE)
- Take cities latitude and longitude from Google geolocator (Python API Geopy)

name	latitude (degrees)	longitude (degrees)	surface (km ²)	density (habs/km ²)
Ozan	46.391534	4.915265	6.6	98.3
Cormoranche-sur-Saône	46.240532	4.830863	9	118.9
Paris	48.856614	2.352222	105.4	21153.9
Lyon	45.764043	4.835659	47.87	10117.0
Tours	47.394144	0.68484	34.67	3888.2
Besançon	47.237829	6.024054	65.05	1797.9
...

34190 cities (instances)

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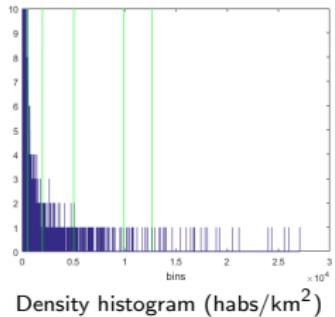
6 Supervised Classification

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- Categorize densities applying clustering (Otsu multi-thresholding)



catégorie 1 : density between 0 and 500 habs/km²
 catégorie 2 : density between 500 and 2000 habs/km²
 catégorie 3 : density between 2000 and 5000 habs/km²
 catégorie 4 : density between 5000 and 10000 habs/km²
 catégorie 5 : density between 10000 and 13000 habs/km²
 catégorie 6 : density greater than 13000 habs/km²

city	latitude (degrees)	longitude (degrees)	surface (km ²)	density (habs/km ²)	density (category)
Ozan	46.391534	4.915265	6.6	98.3	1
Cormoranche-sur-saone	46.240532	4.830863	9	118.9	1
Paris	48.856614	2.352222	105.4	21153.9	6
Lyon	45.764043	4.835659	47.87	10117.0	5
Tours	47.394144	0.68484	34.67	3888.2	3
Besancon	47.237829	6.024054	65.05	1797.9	1
...

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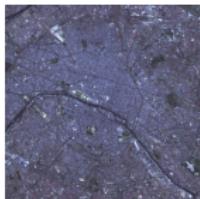
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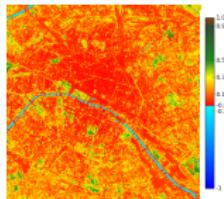
- Data
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- Compute Normalized Difference Vegetation Indice using bands 4 (Red) and 5 (Near-Infra-Red) for each dataset :
- Values between -1 and 1
- ≤ 0 for water, snow and cloud
- = 0 for ground without vegetation
- ≥ 0 for ground vegetation

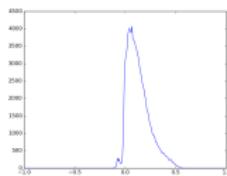
$$NDVI = \frac{NIR - R}{NIR + R}$$



RGB (Paris, May 2013)



NDVI (Paris, May 2013)



NDVI (1024 bins)-histogram
(Paris, May 2013)

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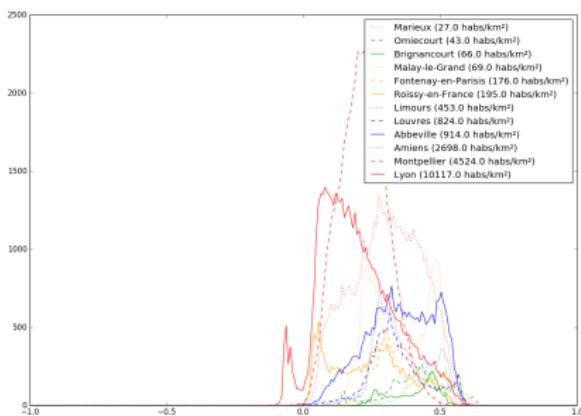
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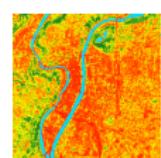
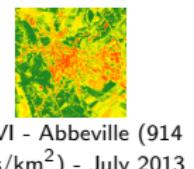
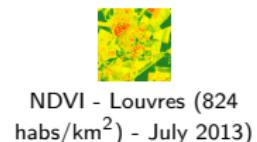
7 Testing classification

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- NDVI histogram could explain human density
 - low ndvi mode for high density (poor vegetation)
 - high ndvi mode for low density (rich vegetation)



NDVI (1024 bins)-histograms (French cities, July 2013)



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- Explanatory variables : NDVI (1024 bins)-histograms of the 34190 cities
- Predictable variable : density of the 34190 cities for regression
- Predictable variable : density category of the 34190 cities for classification

city	bin-1	bin-2	...	bin-511	bin-512	...	bin-1023	bin-1024	density (hab./km ²)	density (category)
Ozan	0	0	...	1	5	...	0	0	93.8	1
Cormoranche-sur-Saône	0	0	...	1	4	...	0	0	118.9	1
Paris	0	0	...	1953	1815	...	0	0	21153.9	6
Lyon	0	0	...	1099	1032	...	0	0	10117.0	5
Tours	0	0	...	268	238	...	0	0	3888.2	3
Besancon	0	0	...	97	122	...	0	0	1797.9	1
...

Very imbalanced data for classification !

category	number of samples
1	32533
2	1252
3	288
4	78
5	15
6	24

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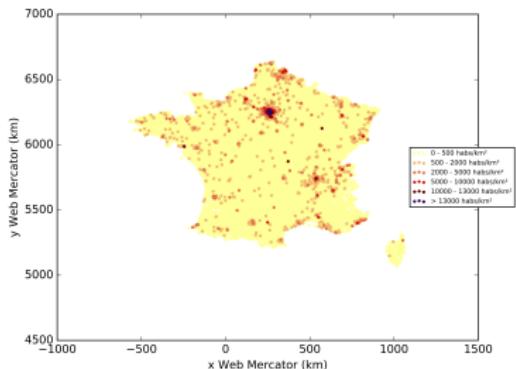
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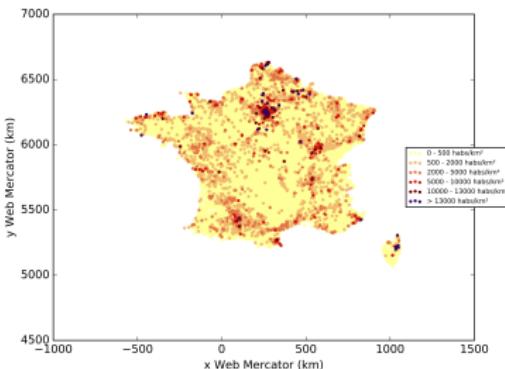
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- Overcome imbalanced data by
 - Majoring error by weights to amplify error on minority class : $w_i = \frac{n_1}{n_i}$.
- Best cross-validation (stratified 3-folds) of 92.26% with one layer (1200 neurons), SGD learning rate of 0.001 and penalization of 0.001.



France density category - ground truth

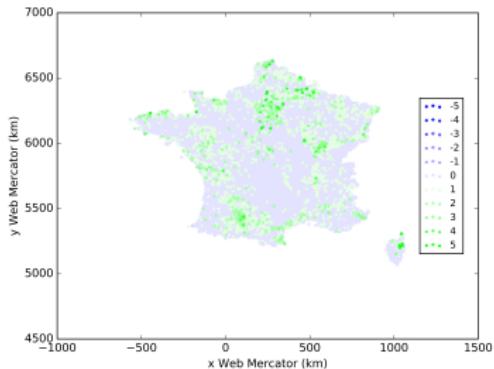


France density category - prediction

Confusion matrix after refitting						
	1	2	3	4	5	6
1	29743	2281	367	95	24	23
2	207	853	164	23	2	3
3	2	36	236	9	2	3
4	0	0	2	76	0	0
5	0	0	0	0	15	0
6	0	0	0	0	0	24

category	mean score
1	91.42%
2	68.13%
3	91.95%
4	97.64%
5	100%
6	100%
total	90.51%

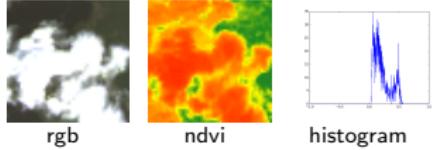
Neural Network



France density classification error ($y_{pred} - y_{true}$)

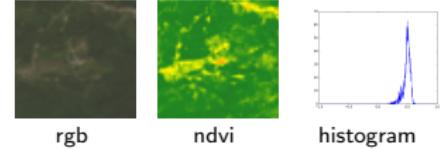
- Green points shows that a lot of low densities (category 1) are predicted as high densities (category 5/6) (see Corsica).
- This can be related to cloudyness that provides zero values for NDVI like high densities does :

Silvareccio
 cloudyness :
 49.5%
 true : 1
 pred : 6
 error : 5



Yousef Kacer

Porri
 cloudyness :
 0.0%
 true : 1
 pred : 1
 error : 0



High-Res satellite images for human density prediction

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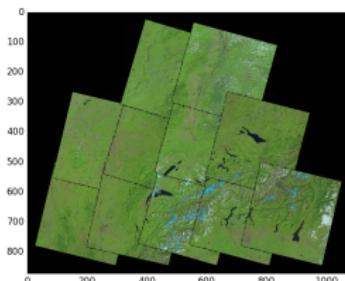
- Take ground truth densities and surfaces for Switzerland (2013), Belgium (2015) and Netherlands (2014).

Switzerland (2013)	
category	number of samples
1	1857
2	428
3	57
4	9
5	1
6	0
total	2352

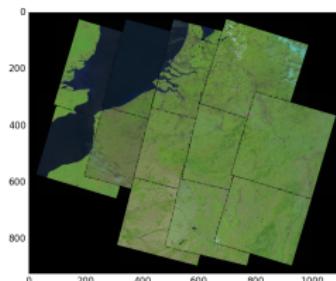
Belgium (2015)	
category	number of samples
1	406
2	154
3	14
4	7
5	1
6	7
total	589

Netherlands (2014)	
category	number of samples
1	234
2	121
3	31
4	1
5	0
6	0
total	388

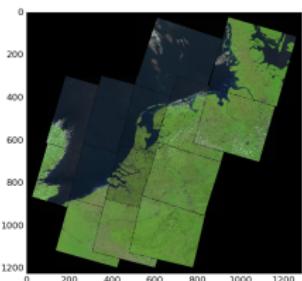
- Take longitudes and latitudes of each city using Google geolocator
- Take corresponding Landsat-8 datasets for each country in the corresponding year (between May and September, day acquisition, cloud covering $\leq 20\%$)



Switzerland datasets georeferenced in Web Mercator system



Belgium datasets georeferenced in Web Mercator system



Netherlands datasets georeferenced in Web Mercator system

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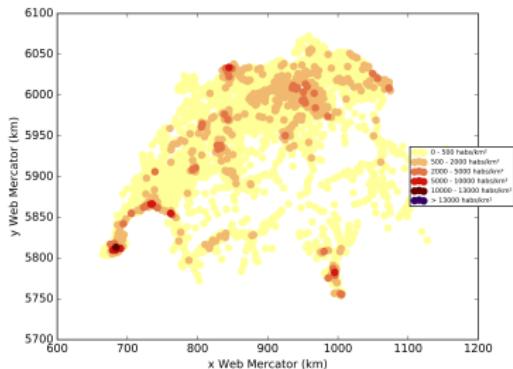
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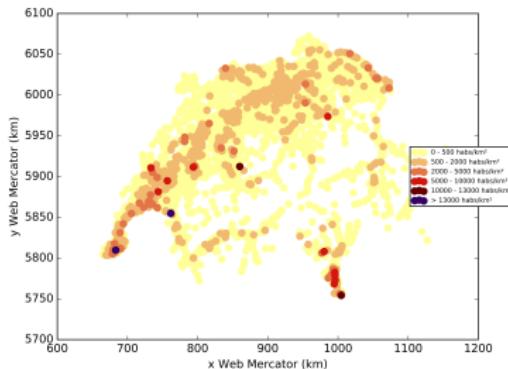
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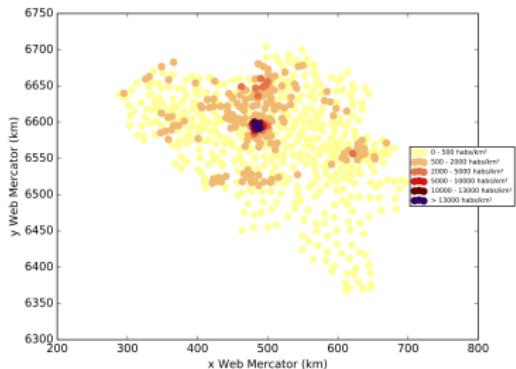
Switzerland density category - ground truth



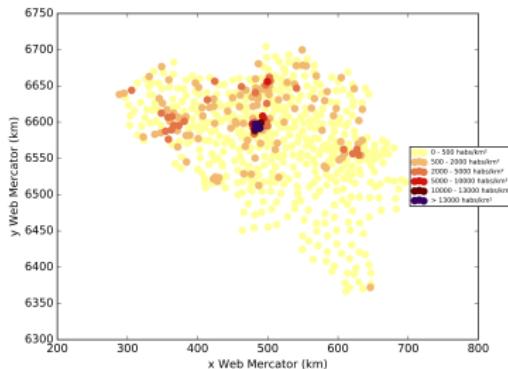
Switzerland density category - prediction

Confusion matrix						
	1	2	3	4	5	6
1	1601	244	7	4	1	0
2	158	249	18	2	1	0
3	2	36	16	3	0	0
4	1	0	5	1	0	2
5	1	0	0	0	0	0
6	0	0	0	0	0	0

category	mean score
1	86.21%
2	58.18%
3	28.07%
4	11.11%
5	0%
6	-
total	79.38%

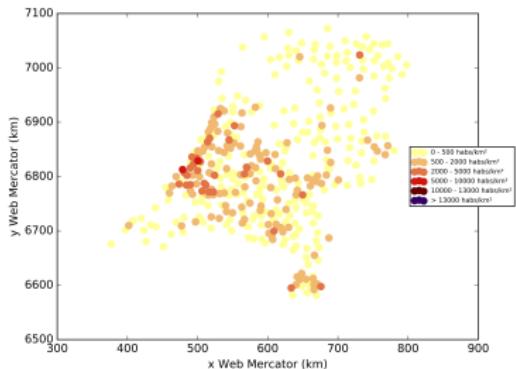


Belgium density category - ground truth

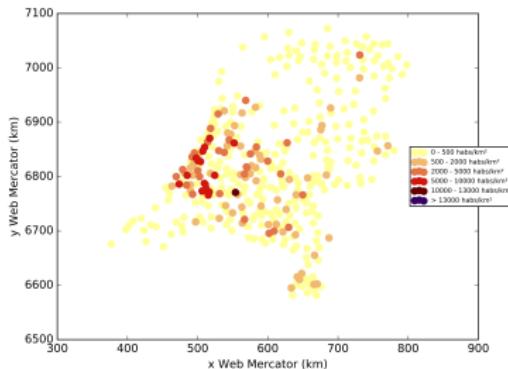


Belgium density category - prediction

Confusion matrix						
	1	2	3	4	5	6
1	363	41	2	0	0	0
2	73	60	19	2	0	0
3	1	6	6	1	0	0
4	1	0	2	2	2	0
5	0	0	1	0	0	0
6	0	2	0	1	0	4



Netherlands density category - ground truth



Netherlands density category - prediction

Confusion matrix						
	1	2	3	4	5	6
1	277	5	2	0	0	0
2	54	47	14	5	1	0
3	2	6	14	9	0	0
4	0	0	1	1	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0