DEFINITION of HRU using Area Fraction Images derived from Spectral Unmixing

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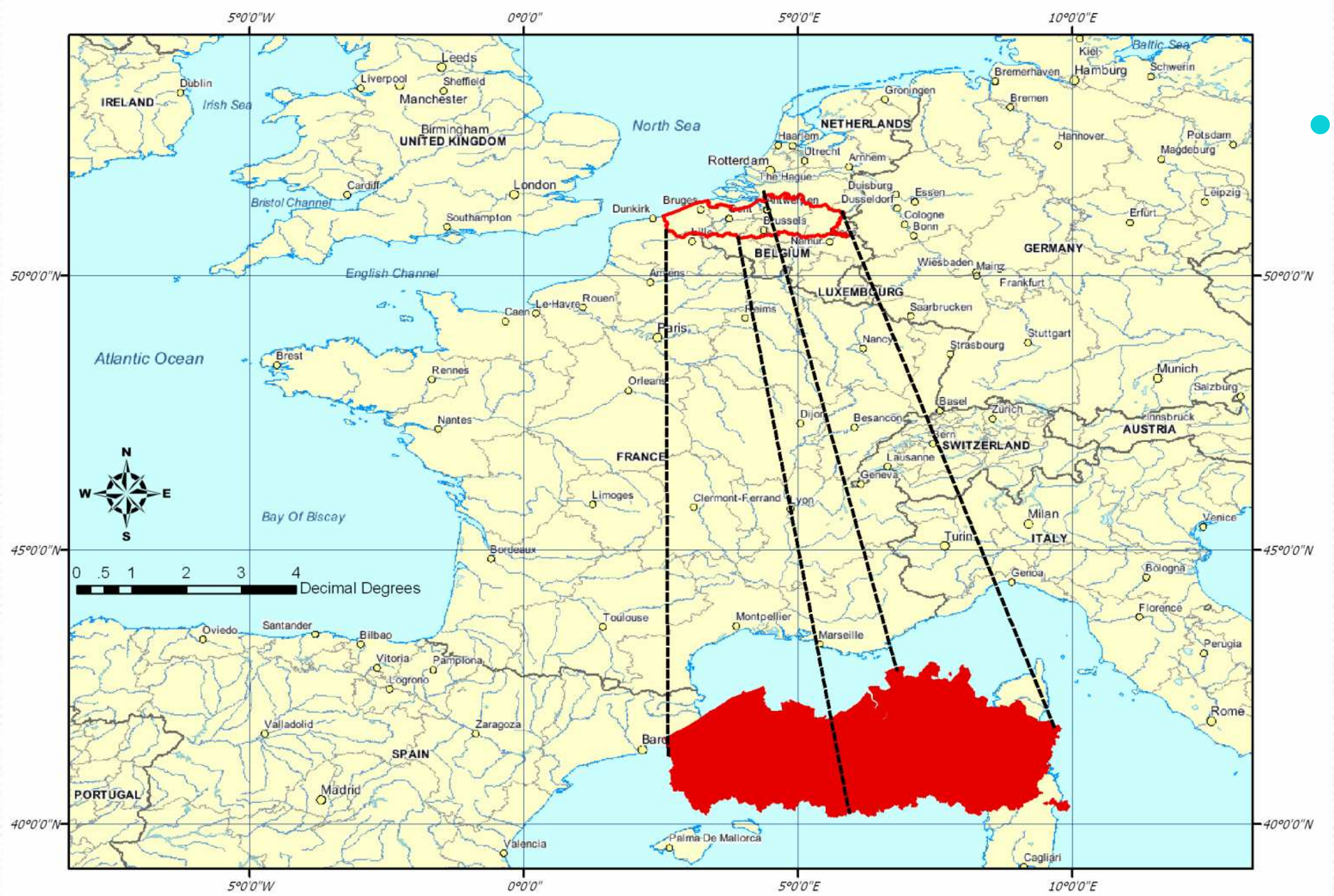
Outline

1. Assessing area fractions of land use classes by means of spectral unmixing of low-cost LR multi-spectral images
   - Linear spectral unmixing
   - Data
   - Results

2. Definition of HRU using area fraction data of land use classes
   - Downscaling of soil data
   - Upscaling of area fraction data

Study Area



- Regions of Flanders and Brussels, located in northern Belgium

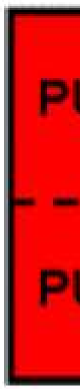
Source: ESRI_World ArcIMS Service

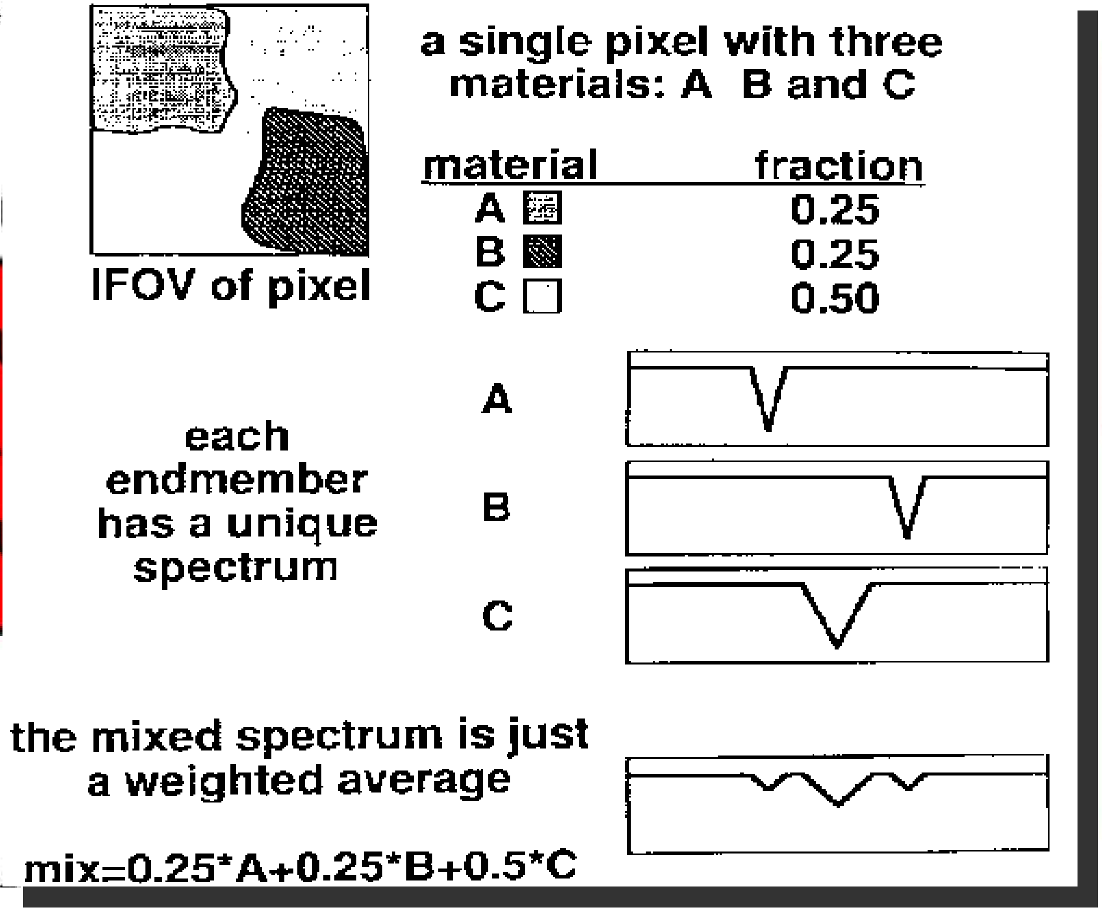
Linear Spectral Unmixing

End-member estimation

Assessment of Land use Area Fractions

Figure 9 : Illustration





Red Fraction Map

Green Fraction Map

Source: Newland,

material) spectrum

Linear Spectral Mixing (Pai-Hui Hsu, 2005)

Multiple end-member spectral mixture analysis

$$R_k = \sum_{i=1}^{M} f_i \, p_{i,k} + e_k$$

- The modeled fractions are typically constrained

$$\sum_{i=1}^{m} f_i = 1 \quad and \quad 0 \le f_i \le 1$$

- $\boldsymbol{R_k}$ is the pixel reflectance for band **k**
- $\boldsymbol{M}$ is the number of end-members
- $\boldsymbol{f_i}$ is the area fraction of end-member **i**
- $\boldsymbol{p_{i,k}}$ is the reflectance of end-member **i** at band ***k***
- $\boldsymbol{e_k}$ is the residual term at band **k**

For an image

- Simplified: $R = FP + \varepsilon$

Determination of End-member spectra: Reversed Linear Unmixing

$$P = (F^T F)^{-1} F^T R$$

- ***P*** is the matrix of End-member spectra
- ***F*** is the matrix of known End-member fractions
- ***R*** is the matrix of input reflectance values

DATA:

Low resolution multi-spectral imagery to be unmixed

- SPOT VGT 10 day composite, 4 spectral bands (Blue, Red, NIR and SWIR), year 2001, spatial resolution 1 km^2
  - Summer & winter totally 13 images selected
- MNF (Minimum Noise Fraction) transformation performed to reduce the noise and decrease the dimensionality of data
  - The 4^{th} band (SWIR) was not used

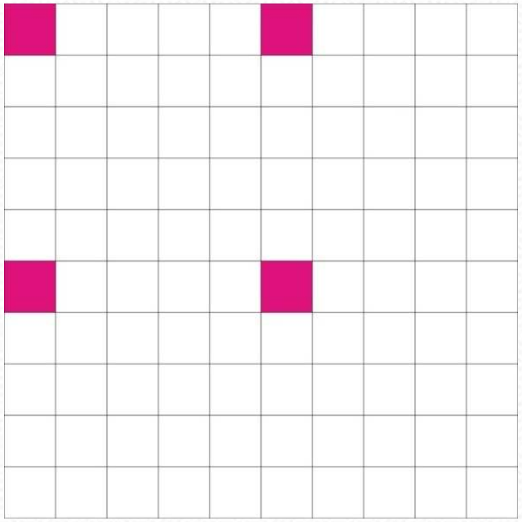
Component 1, 2 and 3 composite of MNF transformation

Red (R), NIR (G), and SWIR (B) composite of 3^{rd} decade of July 2001 shows the SWIR pixel contamination in blue strips

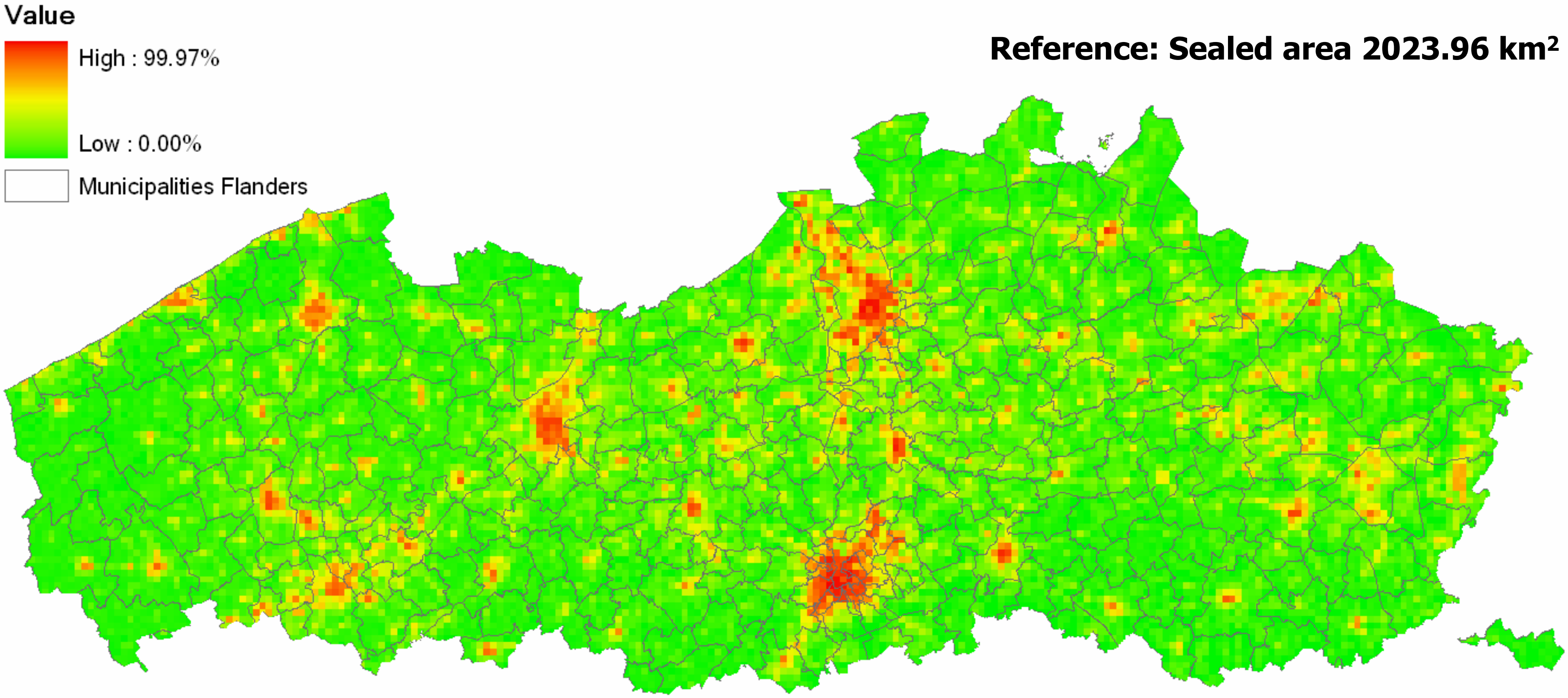
Data: Known end-member fractions

Derived from reference area fraction images

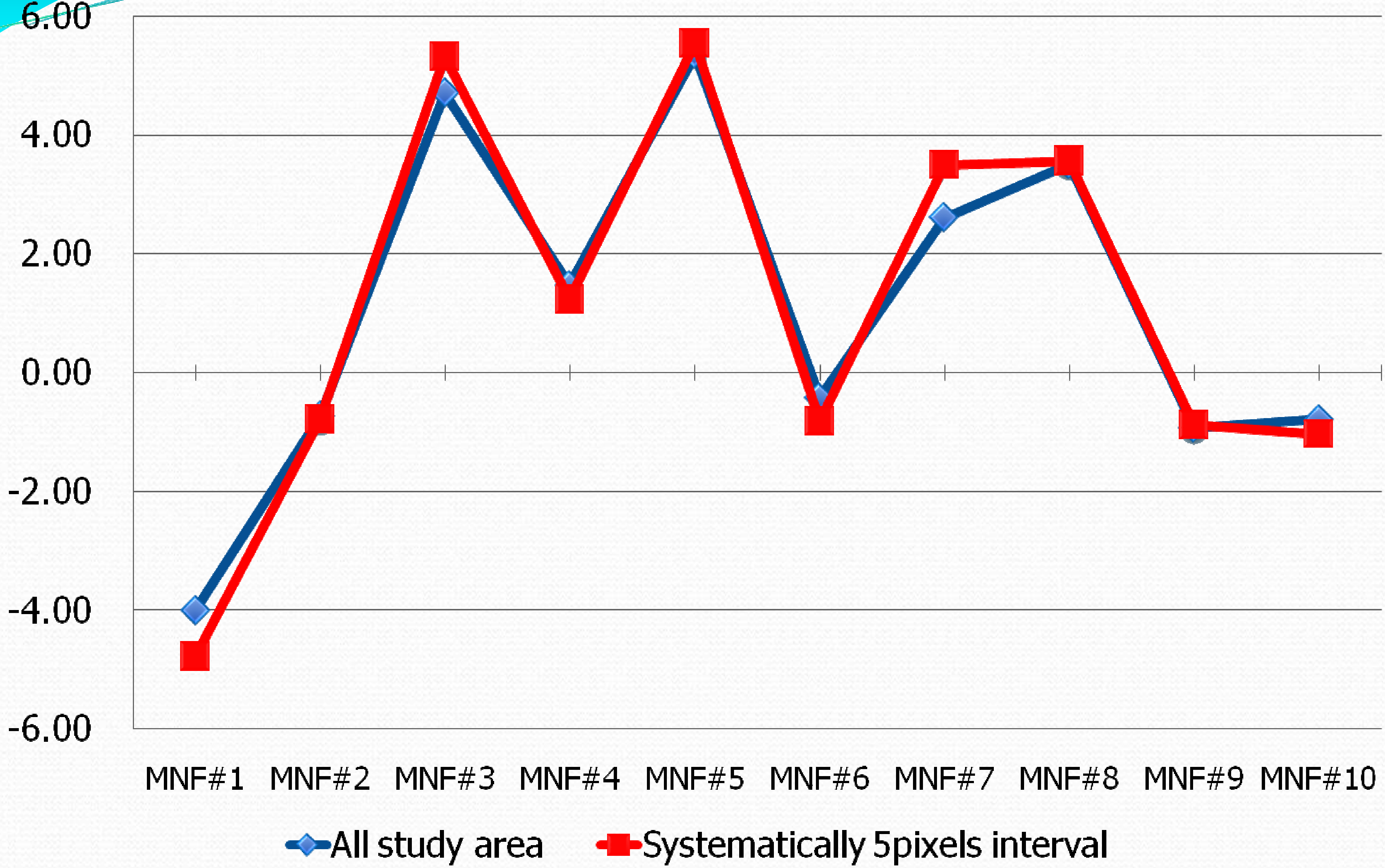
1. All the pixels of study area for which area fraction sum up equal to 100% (10416 pixels of 14310 pixels, 72.98%)
2. Sample of 1 pixel out of each 5 × 5 pixels. Total number of pixels = 416, 2.91% of all pixels



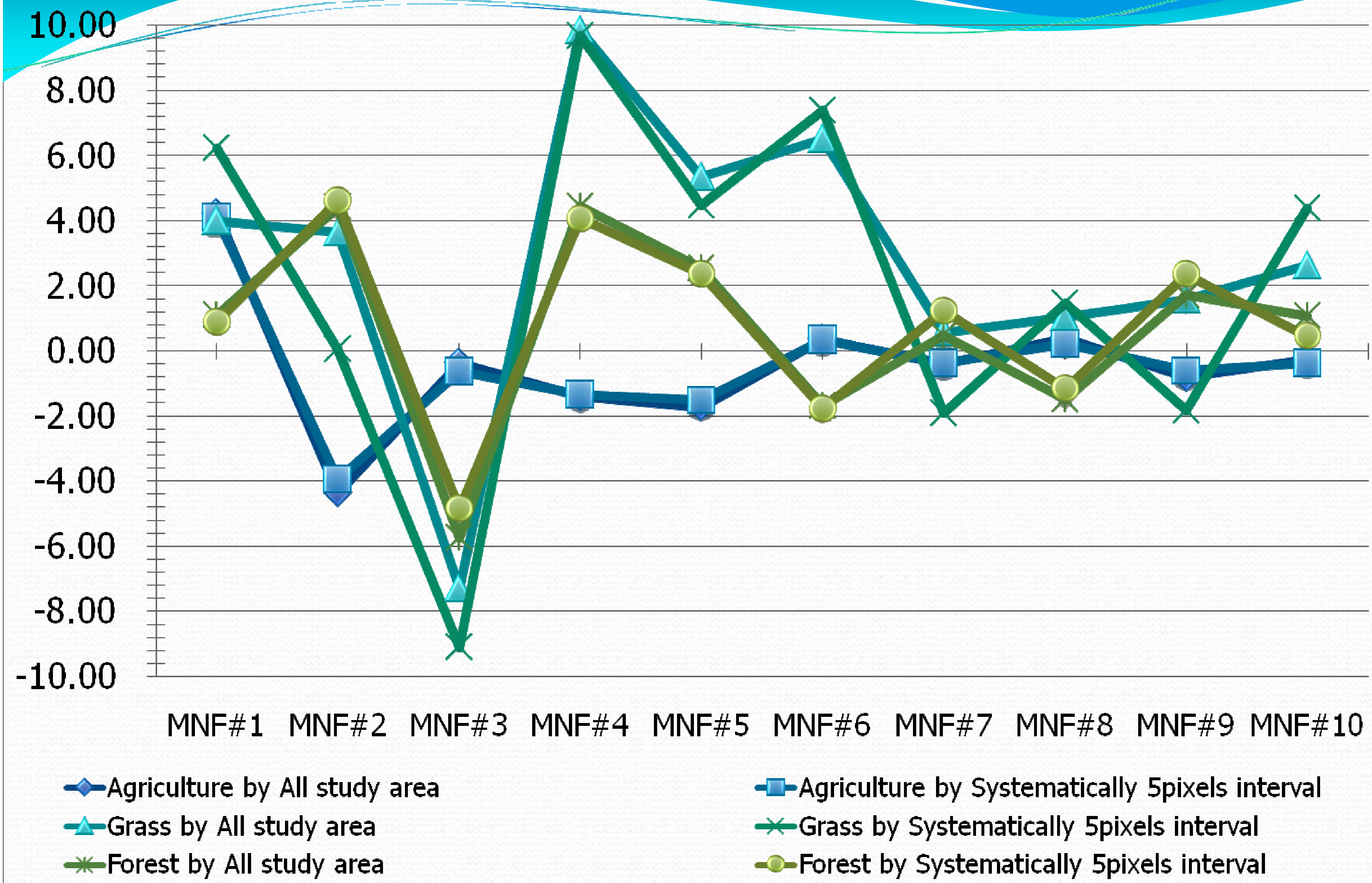
Reference Area Fraction data: Sealed class



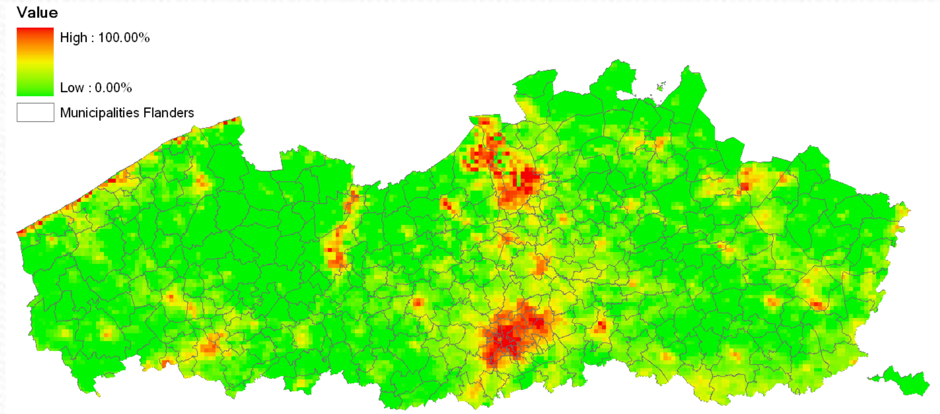
Sealed class Endmember of First 10 MNF bands



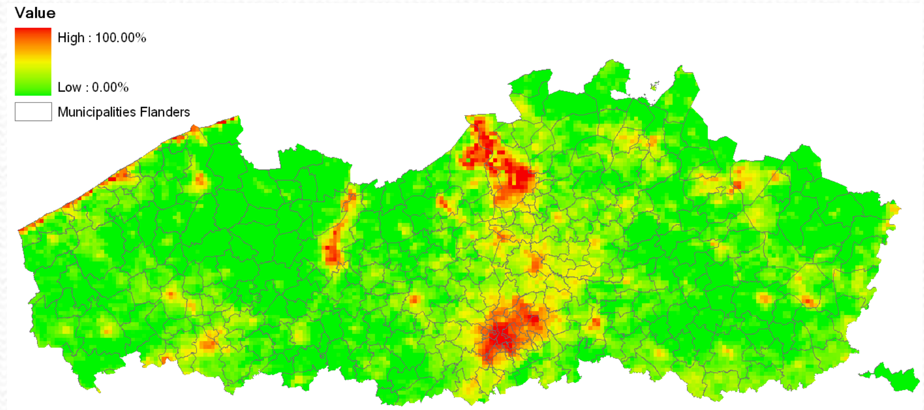
Agriculture, Grass and Forest classes end-members



Estimated Sealed Area Fractions



End-member estimated by all pixels



End-member estimated by 5 pixels interval

End-member estimation method	**RMSE**			**Sealed Area (km²)**	**Abs Difference vs. Reference(km²)**	**Difference with reference (%)**
	Per Pixel (%)	Per Municipality (km²)	Per Municipality (%)			
Pixels of all study area	16.77	4.85	11.61	2020.54	3.42	0.17
Systematically 5pixels interval	16.87	4.91	11.84	2116.46	92.50	4.57

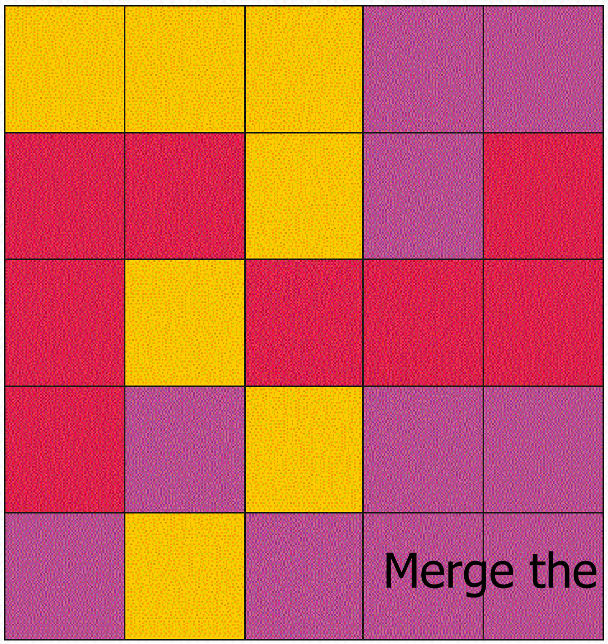
Reference: Sealed area 2023.96 km²

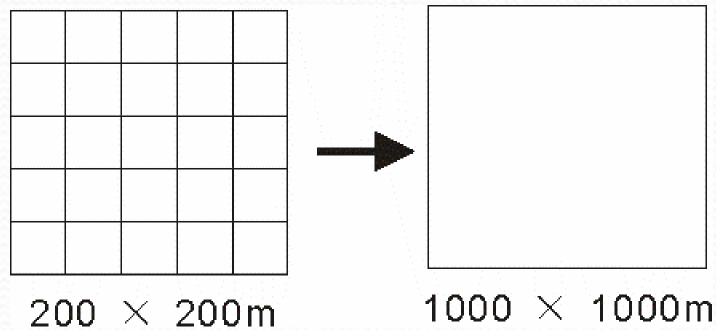
How to combine AFI and a soil map to generate HRU?

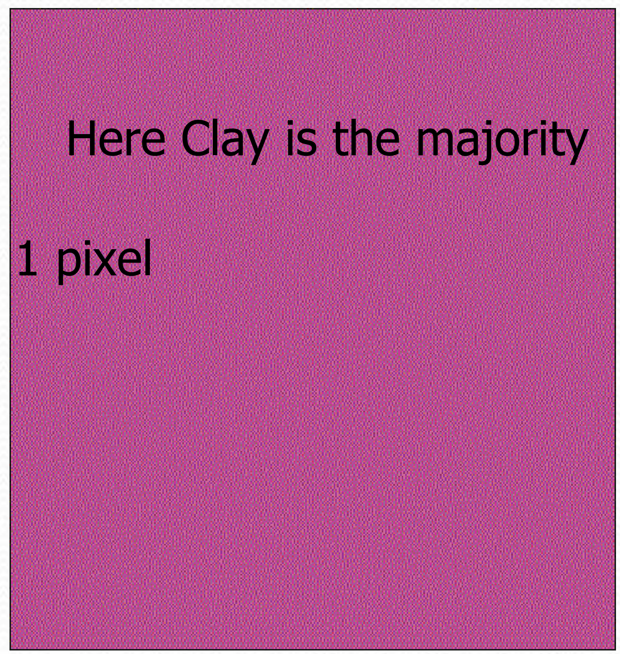
Downscale soil map information towards the resolution of the AFI

Upscale the AFI to the resolution of the soil map

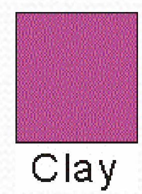
Downscale (soil map)



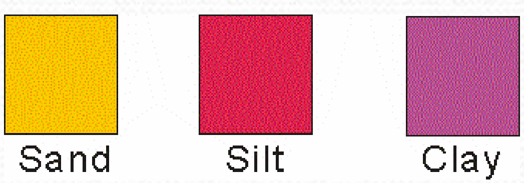




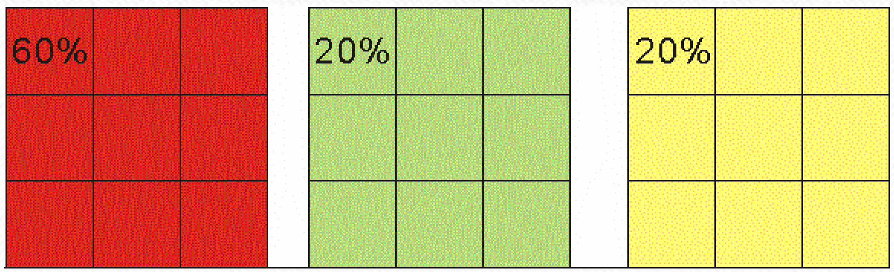
Merge the 25 pixels to 1 pixel



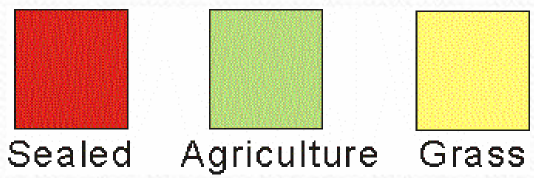
Soil map with 40.000 m^2 spatial resolution



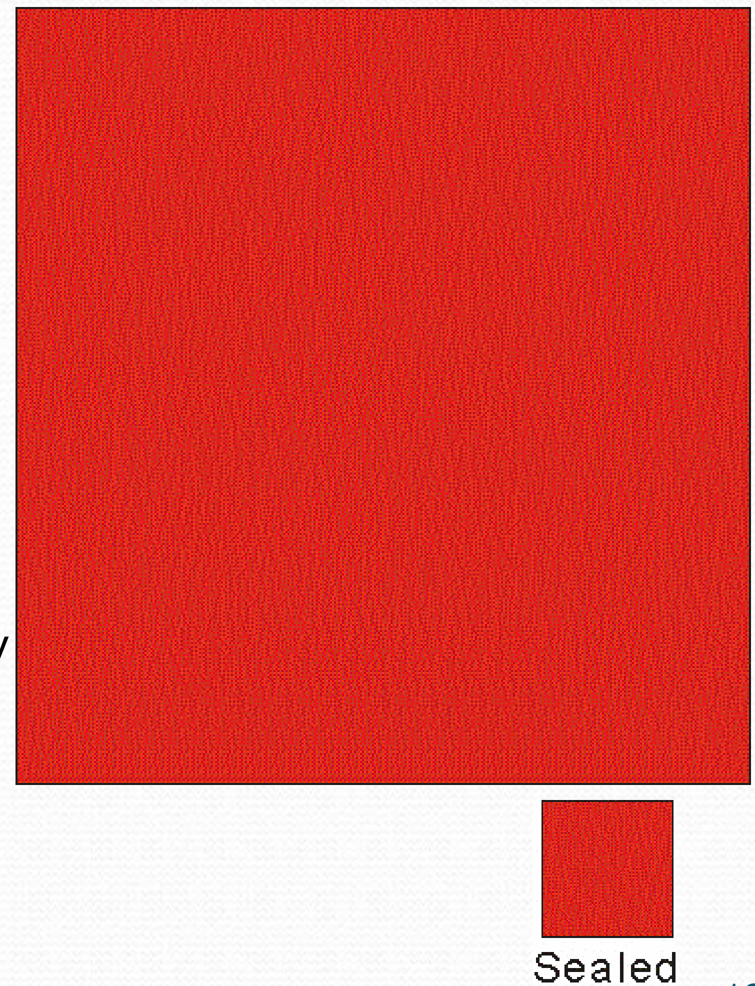
Downscale (Area Fractions maps)



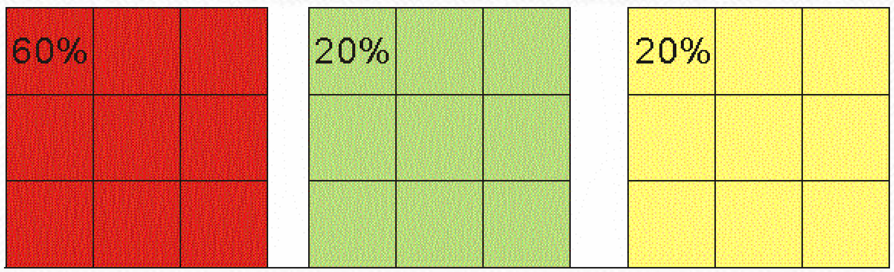
Area Fraction Images with 1 km^2 spatial resolution



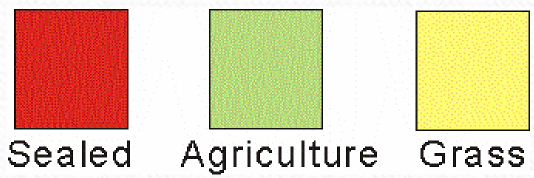
e.g. The top left corner pixel, sealed class is the majority

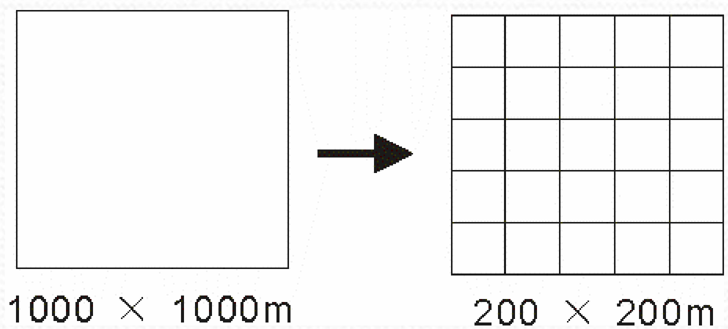


Upscale (e.g. top left corner pixel)



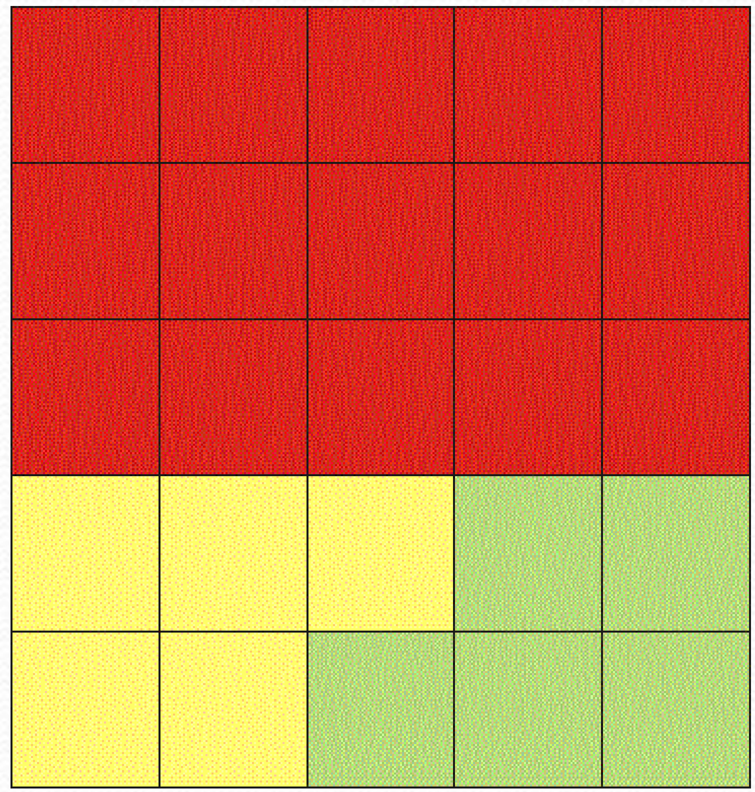
Area Fraction Images with 1 km^2 spatial resolution



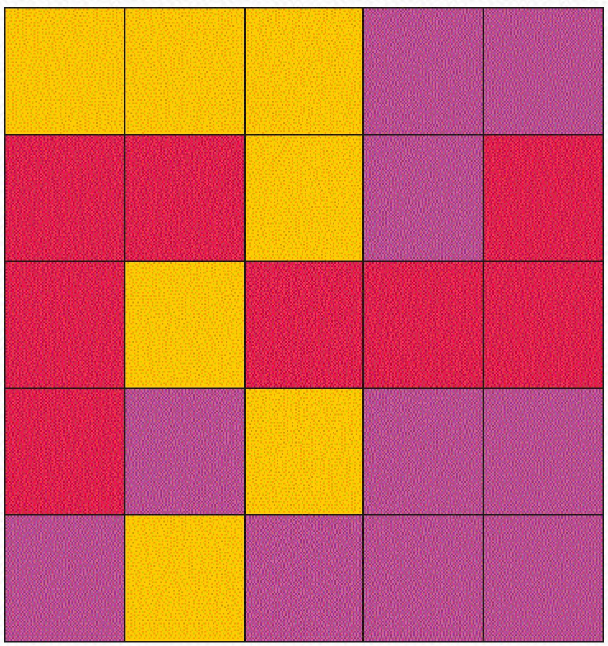


1 pixel sub-divided to 25 pixels

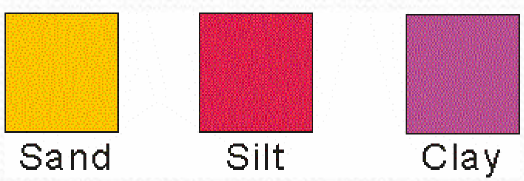
Randomly
Spatial Dependence considered

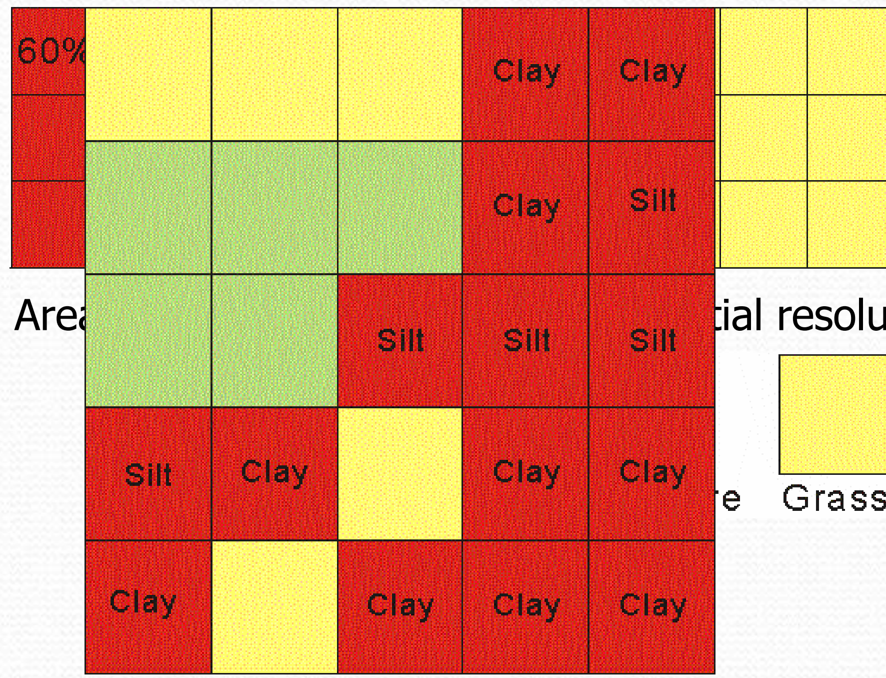


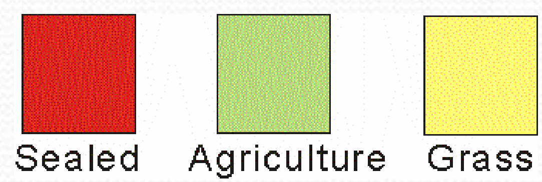
Up scale with soil type factor



Soil type map with 40.000 m^2 spatial resolution







Here both soil type and spatial dependence considered

Conclusion

- The accuracy of the AFI obtained for the sealed land use class are too low for operational use.
- The spatial distribution of the sealed areas is not well captured due to the too coarse spatial resolution of the SPOT-VGT-sensor, the too limited spectral information used (blue, red and near infrared-bands only) and the MNF-transformation possibly violating the assumption of linear mixture (Lobell and Asner, 2004).
- Possibilities for combining land use AFI with soil information have been identified but remain to be functionally evaluated

Future work

- Use of middle resolution imagery, e.g. TERRA-MODIS (250 m * 250 m and 500 m * 500 m), ENVISAT-MERIS (300 m * 300 m);
- Use of more spectral bands;
- Use of one summer and one winter image only so that MNF-transformation would no longer be required;
- Use of alternative unmixing methods. For agricultural land use ANN seem to be most promising in this respect (Verbeiren et al., in press).
- Evaluation of combination of AFI with soil map to generate HRU

THANKS

QUESTIONS?