# Production of forest biomass maps using NFI field data and remote sensing

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# Information of forest biomass resources - bioenergy

- Source of bioenergy
  - planning of the structure of energy economy
  - estimation of bioenergy resources in the form of thematic maps
  - availability bioenergy resources in an area or for a project
- Renewable energy sources 25 % of energy consumption in Finland (2004)
- Wood and wood-based fuels play an important role in the decentralised energy system in Finland

# Carbon balance of forests

- Forest biomass is an important factor in modelling of carbon balance
- Thematic biomass maps:
  - Can be used in the GHG inventory when estimating carbon losses & gains of land-use change
  - Methodology could be applied in tropics with REDD (Reducing Emissions from Deforestation and Degradation)
  - Could be used as a starting point for a process-based model to predict carbon balance under climate change

# Multi-source national forest inventory (MS-NFI)

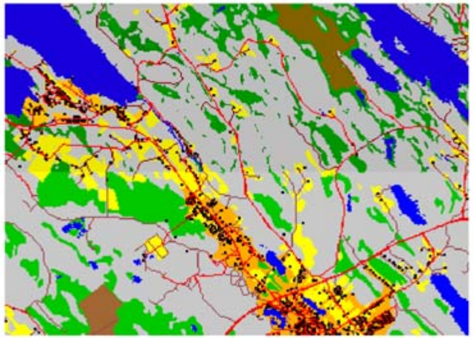
- From the NFI8 multi-source forest inventory technique has been applied for producing data of forest resources in the form of thematic maps and forest statistics for areas of various size
- The method utilizes field sample plots, satellite imagery and digital maps
- MS-NFI produces estimates at
  - municipality
  - forest estate
  - forest stand
  - sub-stand levels (down to pixel size of 25 x 25 m).

# MS-NFI – technique

**Field measurements**

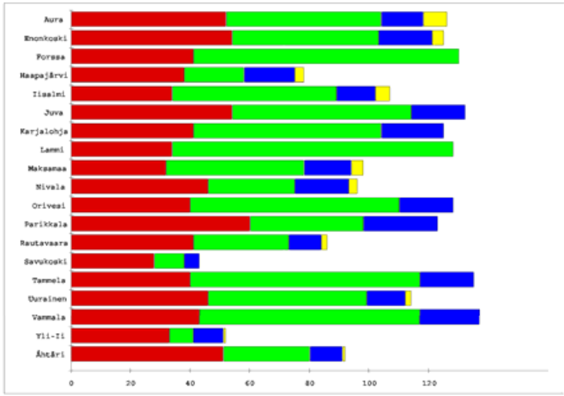
**Satellite images**

**Digital map-data**

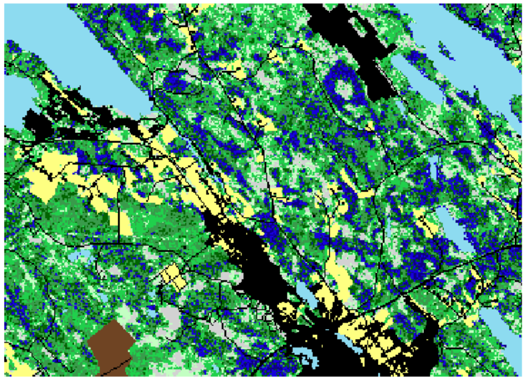


## Processing of data

**Forest statistics**




**Thematic maps**



# Objective

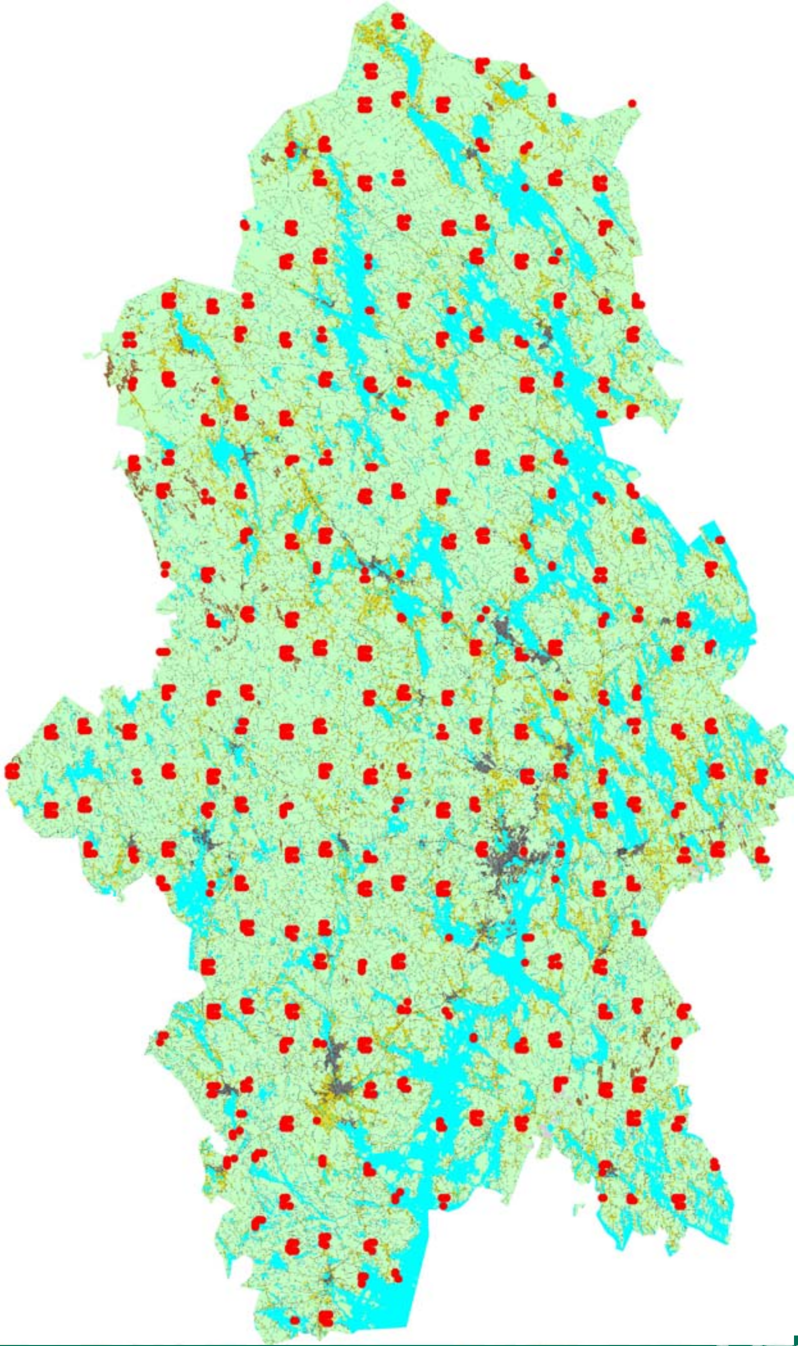
- Testing multi-source national forest inventory technique in producing map-form biomass estimates (biomass maps)

# Study material

- 2199 NFI10 sample plots from Central Finland (Keski-Suomi) measured between 2004—2006
- Only forestry land plots included
- Biomass components (foliage, branches, stem, aboveground and belowground biomass) modelled on the basis of tree-level NFI data (Repola et al. 2007)
- For biomass estimation the tree species were assigned to the following groups:
  - Pine group (*Pinus sp. & Larix sp*.) 46 %
  - Spruce group (*Picea sp., Abies sp. & Juniperus communis*) 31 %
  - Birch group (*Betula sp., Populus sp., Alnus sp., Salix sp., Sorbus aucuparia* & other broadleaved sp.) 23 %
- Biomass models for pine, spruce and birch applied respectively for the species groups

# Study area and NFI plots

- NFI10 sample plots measured in Central Finland 2004-2006



# Satellite imagery

- The Central Finland study area  was covered by 5 Landsat 5 TM image scenes :
  - path 190, row 16-18, date 17.07.2006
  - path 191, row 15-16, date 05.07.2005
  - path 190, row 14-16, date 31.08.2005
  - path 188, row 15-17, date 02.09.2005
  - path 190, row 14-15, date 17.07.2006
- Digital map data was used for excluding other land use classes than forest

# Modelling biomass variables from NFI data 1

- On NFI plots, diameter at breast height is obtained for every relascope-sampled tree
- Sample tree characteristics (such as total height and ratio between height and height to the living crown) generalized over the tally trees with non-linear mixed models
- Estimates of foliage and branch biomass were modelled on the basis of diameter, height and living crown length
- For stem biomass stem wood density models by Repola et al. (2007) containing diameter, tree age and temperature sums and volume functions by Laasasenaho were combined

# Modelling biomass variables from NFI data 2

- The total aboveground biomass was the sum of foliage, branch and stem biomass.
- Belowground biomass was computed using the summed up estimations of stump biomass and biomass of roots
- Estimations per tree converted to values per ha

# Variables estimated

- Aboveground biomass*
- Belowground biomass*
- Biomass of branches*
- Biomass of foliage/needles*
- Stand volume (traditional MSNFI variable estimated as a thematic map) as a reference

*Total biomass and divided between tree species groups (pine group, spruce group and deciduous)

# Method for estimating biomass variables

- *K*-nearest neighbor estimation method (3-5 nearest neighbors applied depending on the total number of NFI plots covered by satellite image)
- Assumption: NFI sample plots having similar biomass characteristics also have similar satellite image spectral features
- Biomass variable estimates were calculated as weighted averages of the measured biomass variables of the k nearest NFI plots

# Results

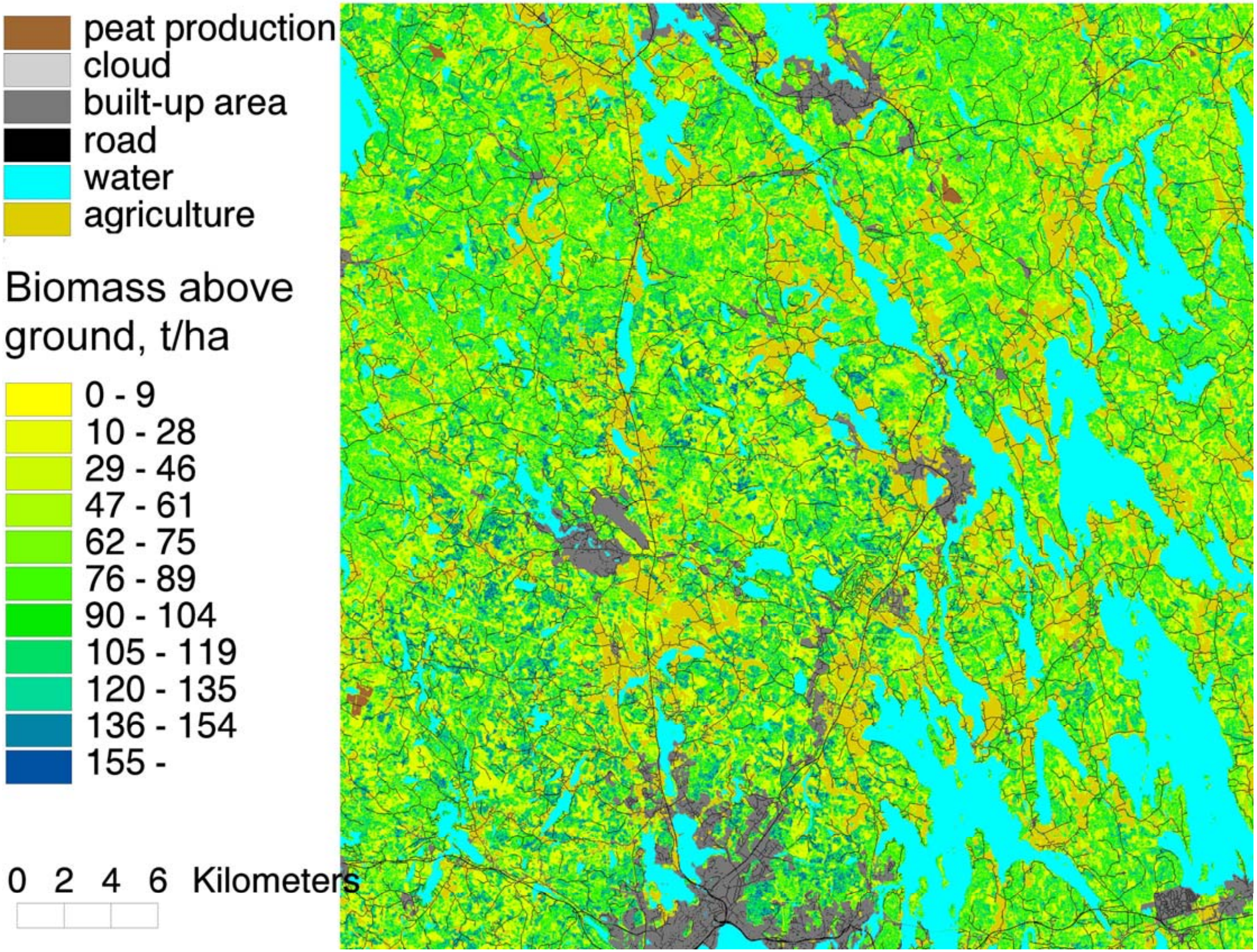
- Accuracy of the estimates of biomass variables (tree species groups summed together) were on a similar level as typical MSNFI variables (such as stand volume)
- Biomass estimates per tree species were not successful

# Cross-validated estimation results

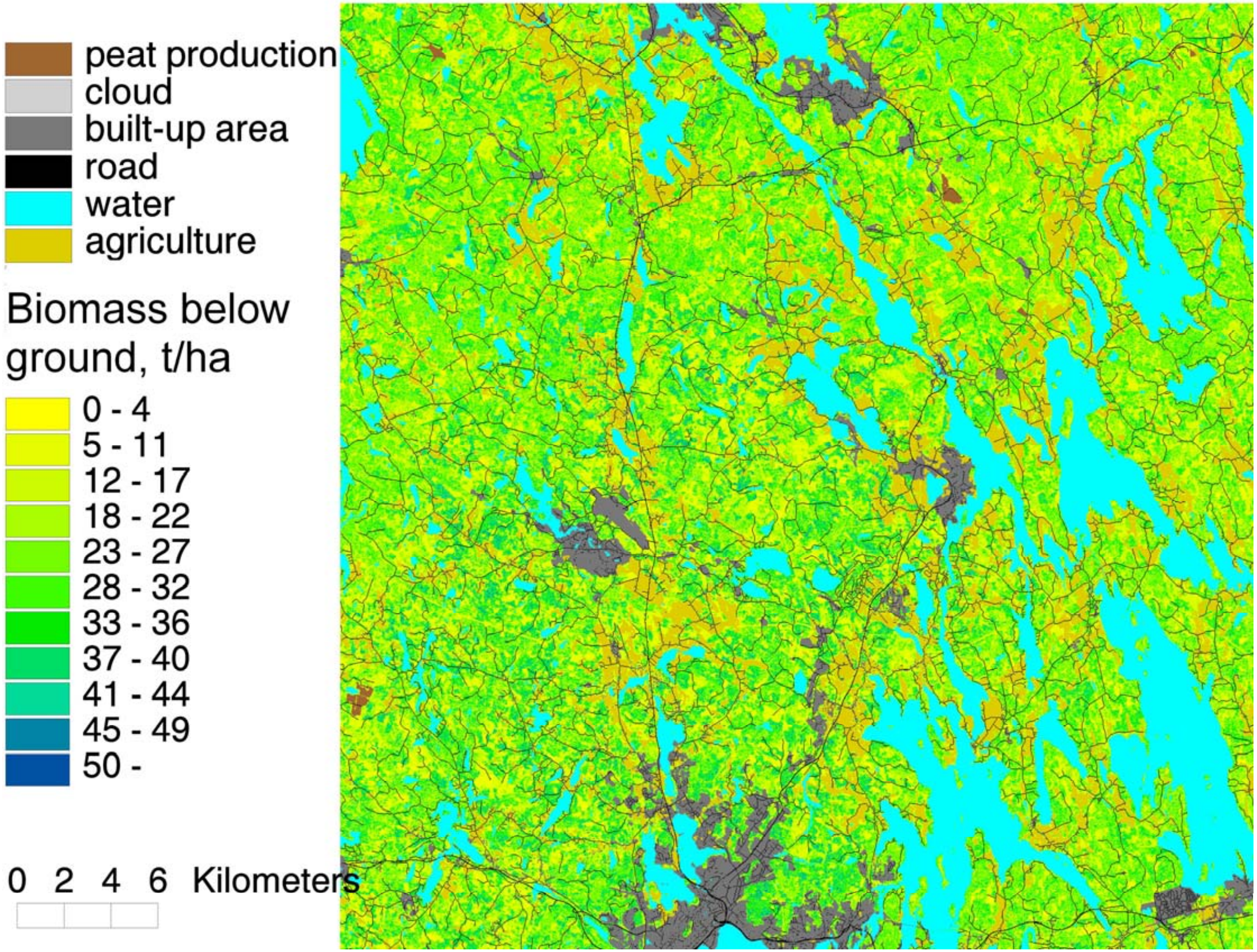
| Variable | Mineral soil Estimate | Mineral soil RMSE % | Mineral soil Bias % | Peatland Estimate | Peatland RMSE % | Peatland Bias % |
|---|---|---|---|---|---|---|
| Stem volume | 142.3 | 67.9 | -1.2 | 100.9 | 71.3 | -0.9 |
| Stem biomass | 56.7 | 69.7 | -1.2 | 41.2 | 73.2 | -1.3 |
| Biomass of branches | 10.9 | 60.3 | -1.1 | 7.8 | 61.6 | -1.8 |
| Biomass of needles/foliage | 5.4 | 64.8 | -1.1 | 3.8 | 69.5 | -3.2 |
| Total aboveground biomass | 73.0 | 66.0 | -1.2 | 52.8 | 69.6 | -1.5 |
| Total belowground biomass | 22.4 | 59.6 | -1.2 | 17.0 | 65.4 | -1.1 |

| Variable | Mineral soil Estimate | Mineral soil RMSE % | Mineral soil Bias % | Peatland Estimate | Peatland RMSE % | Peatland Bias % |
|---|---|---|---|---|---|---|
| Aboveground biomass, pine group | 36.6 | 92.3 | 1.2 | 33.2 | 82.6 | 2.1 |
| Aboveground biomass, spruce group | 22.6 | 161.7 | -3.9 | 9.8 | 213.5 | -5.6 |
| Aboveground biomass, broadleaved | 13.8 | 177.9 | -3.2 | 9.8 | 184.8 | -9.6 |

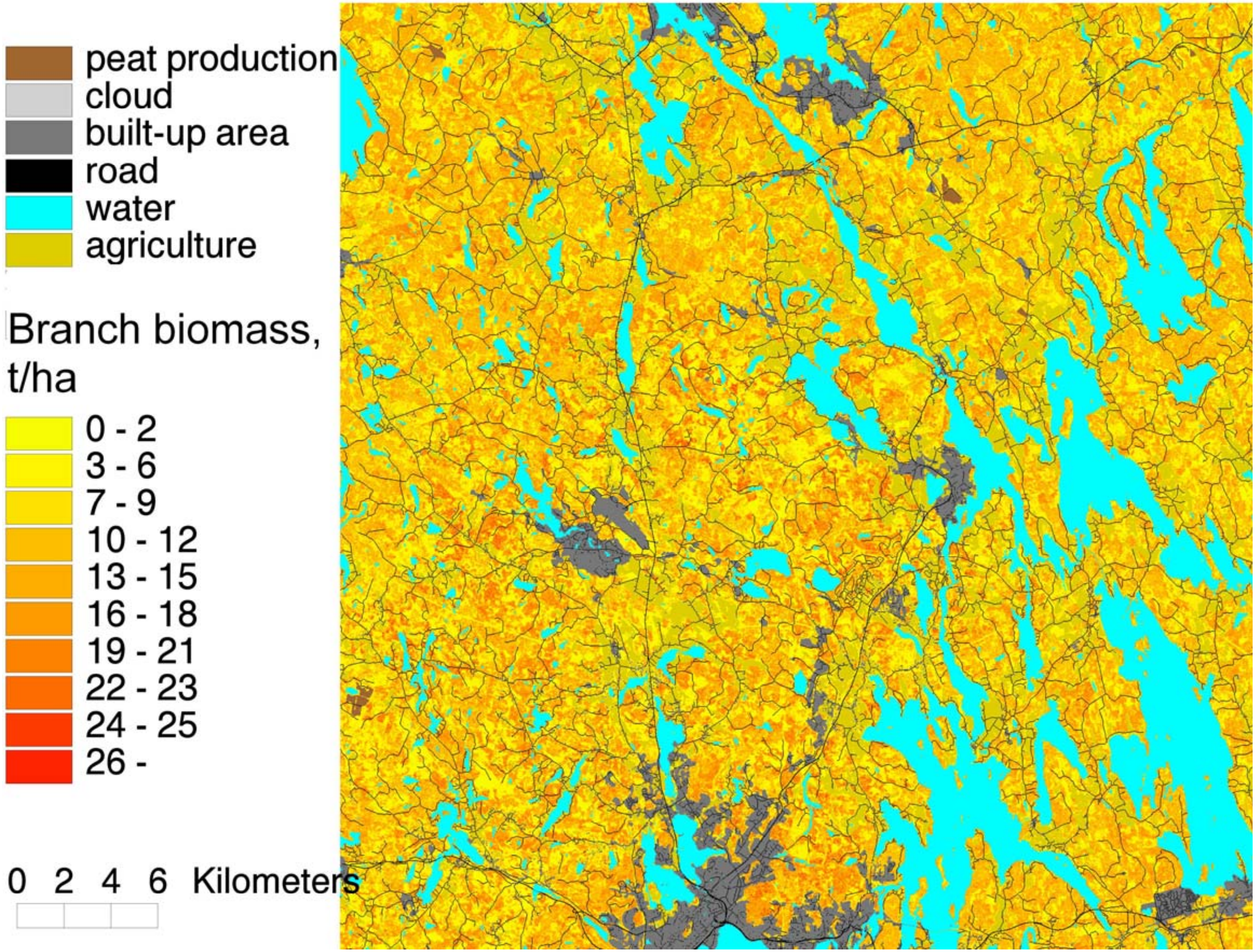
# Map of above ground forest biomass, near town of Jyväskylä



# Map of below ground forest biomass



# Map of branch biomass



# Conclusions

- MSNFI technique can be applied to the estimation of biomass variables in a similar way as traditional forest inventory variables
- Biomass correlates relatively well with satellite image information
  - biomass, especially branch and leaf/needle biomass, major factor in satellite image reflectance
- Separation of tree species not successful (as often the case is with stand volumes)