Geographic Information Systems (GIS) in Environmental Research

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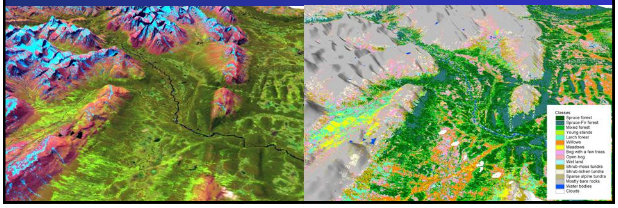
Content:

1. What is GIS?
2. What it can give for Ecological and Environmental Research?
3. Examples from EU-projects: TUNDRA, SPICE, GLIMPSE, E-lup, CARBO-North
4. Example from Ecology: Autumnal moth outbreaks and birch damage mapping and modeling



Geographical Information System

GIS (*Geographical Information System*):

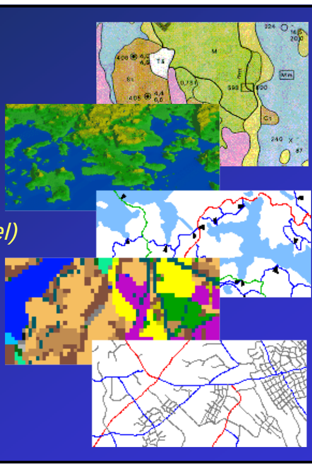
- Computer based system, where space related information can be collected, saved, processed and presented
- Typically consists form different sub-programs
- In present systems they are coming all the time better integrated
- In a broader sense, GIS includes computers (*hardware*), programs (*software*) and users (*humanware*)

Some terms in GIS:

- Geoinformation is data with spatial connection:
  - Data object
  - Coordinate information defining data location
- Map object:
  - Whatever thing or object that can be presented on the map (point, line, polygon, pixel)
- Attributes:
  - Description for the map object
- Topology:
  - Defines the relationships between the map objects

Examples from GIS data:

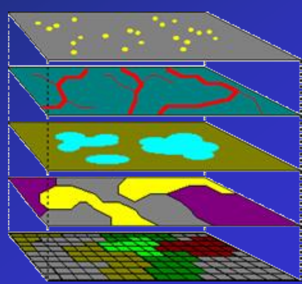
- Soil and geology
- Land forms *(DEM; Digital Elevation Model)*
- Hydrology
- Vegetation
- Roads



In GIS data is arranged to thematic layers:

Different theme types:

- *points*
- *lines/arcs*
- *polygons*
- *rasters/grids*



- GIS allows analyses and visualisations of the relationships between different thematic layers

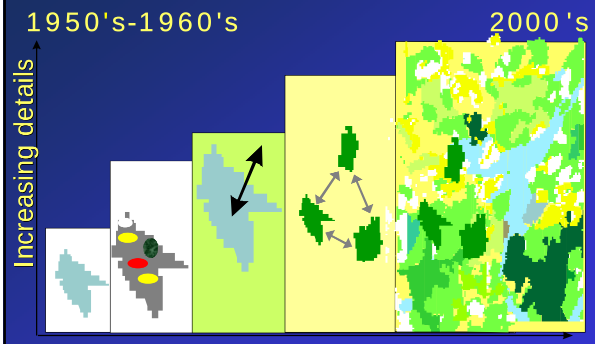
Examples from GIS-programs:

- ArcGIS, ArcView & ArcINFO from ESRI-company:
  - "ArcInfo is the most complete and extensible GIS available ":
  - http://www.esri.com
- MapInfo is another widely used lisence requiring GIS program:
  - http://www.mapinfo.com/
- GRASS is the most used free source-code program:
  - http://grass.itc.it/

Why GIS?

- GIS can give to answers questions like "How some spatially variable biological (or other) phenomena is related to other biological or environmental factors? "
- More specifically:
  - Where does species/community A exist?
  - Where it is in relation to species/community B?
  - How it is located in relation to environmental factors x, y & z?
  - How its location could change if environmental factor x will change?

Spatial Variation in Ecological theories:



GIS in Habitat Modelling:

- Different species uses environment in different spatial scales: this can be analysed with GIS

Ecological / Environmental GIS analyses:

- How the amount, composition and configuration of the habitat patches will impact to size of animal / plant populations?
  - Edge effects, distribution channels, etc.
- How do ecosystem components A, B & C contribute to material intake / export from the watershed X?

GIS in Research Projects, 1

- Especially EU, but also other research funders, like to fund large projects with general and integrative results
- This comes from the needs of policy makers (who have impact on reseach funders)
- In best cases, synergy is achieved when researchers from different fields will co-operate
- Thus, nowadays in many/most of the large research projects has a GIS-part

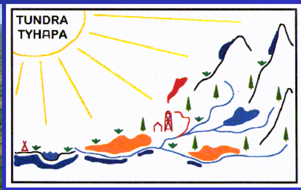
GIS in Research Projects, 2

In projects GIS will help to:

1. Gather data together
2. Allows / makes easier to analyse different data sets together
3. In GIS data can be well visualised and it is easy make presentaation material for different medias, like for www
4. GIS is very useful in watershed studies

Arctic Feedbacks to Global Warming:Tundra Degradation in the Russian Arctic - TUNDRA

Homepage:
http://www.ulapland.fi/home/arktinen/tundra/tundra.htm



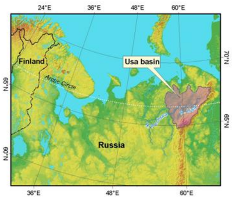
Main research themes:

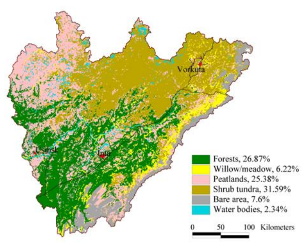
1. Climate and permafrost models
2. Treeline changes
3. Carbon stocks and fluxes
4. Discharge
5. Pollution

In the following I present some GIS-based data produced in the project, and some main results

Research area: Watershed of the Usa

- In Komi & Nenets, NW European Russia
- About 94 000 km^2
- Vegetation zones from taiga via forest-tundra to tundra
- Ural-mountains in the east, area mainly covered by lowlands

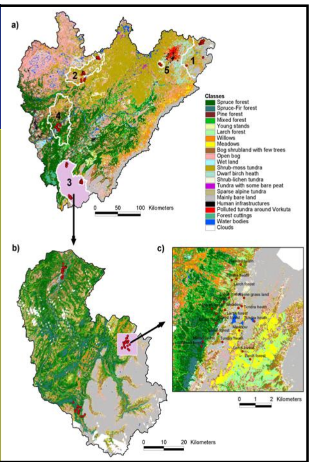




Vegetation classification

- Based on Landsat TM satellite image mosaic

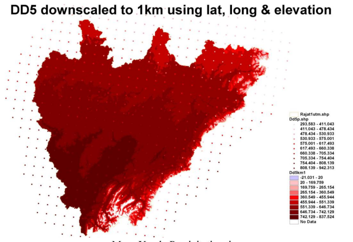
N:o	Class	
	Area (km^2)	93484
1	Spruce forest	12.2%
2	Spruce-Fir forest	0.5%
3	Pine forest	0.6%
4	Mixed forest	7.3%
5	Birch dominated stands	3.2%
6	Larch forest	-
7	Willow complex	7.5%
8	Meadows	2.0%
9	Bog partly with few trees	7.4%
10	Open bog	16.6%
11	Wetland	4.7%
12	Shrub-moss tundra heath	16.7%
13	Dwarf Birch heath	4.0%
14	Dry shrub-lichen tundra	4.7%
15	Dry tundra with some bare peat	1.1%
16	Sparse alpine tundra	1.1%
17	Naturally mainly bare land	6.5%
18	Cities, villages, and industrial	0.4%
19	Human impact tundra-shrublands	0.3%
20	Forest cuttings	0.3%
21	Water bodies	2.8%



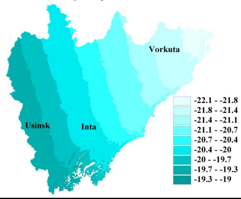
Climate data

- Based on climate model of Danish meteorological institute and some downscaling using regression methods applied in GIS

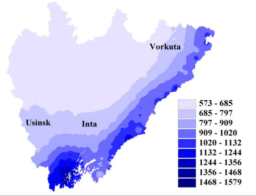
DD5 downscaled to 1km using lat, long & elevation



Mean January Temperature

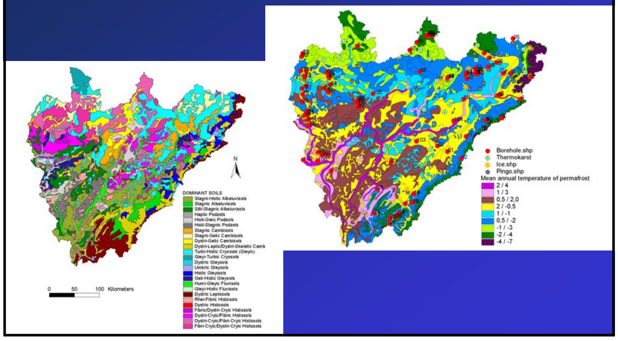


Mean Yearly Precipitation, in mm



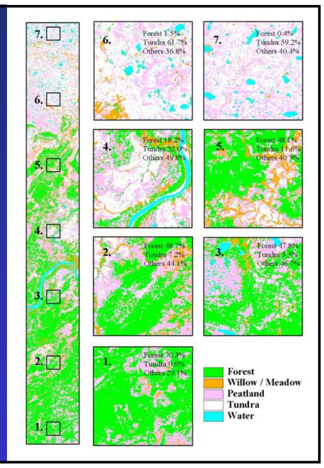
Permafrost & soil maps:

- Polygon based maps produced by Komi Biological Institute & Vorkuta geological survey

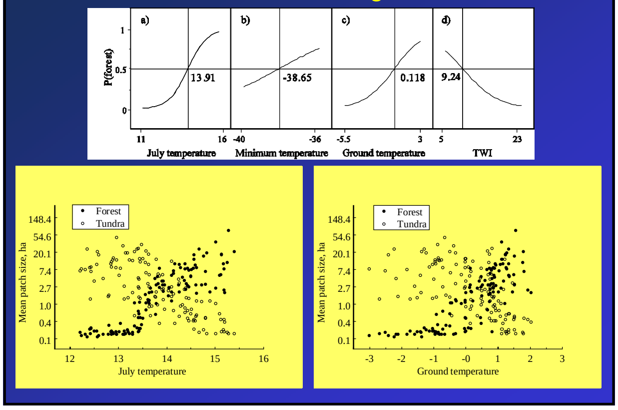


Forest line location modeling, 1

- In the left 25 km wide and 160 km long transect from the middle of the Usa basin showing the main vegetation types in the area
- In the right seven 5 x 5 km sized more detailed views to the landscape (pixel size 30 x 30 m)
- Mainly spruce (*Picea obovata*) formed forest line in the region is actually 100 to 140 km long forest-tundra transition zone

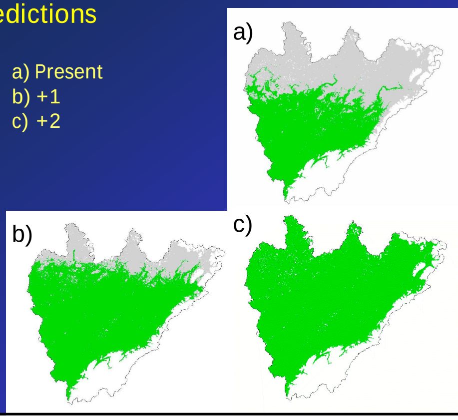


Forest line location modeling, 2



Forest line location modeling, model predictions

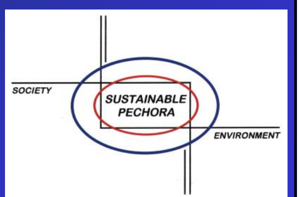
a) Present
b) +1
c) +2



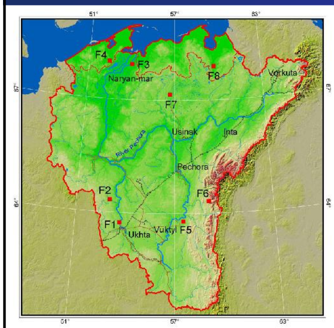
Sustainable Development of the Pechora Region in a Changing Environment and Society - SPICE

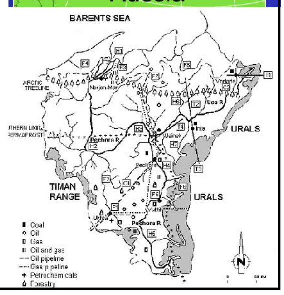
Homepage:

http://www.ulapland.fi/home/arktinen/spice/spice.htm



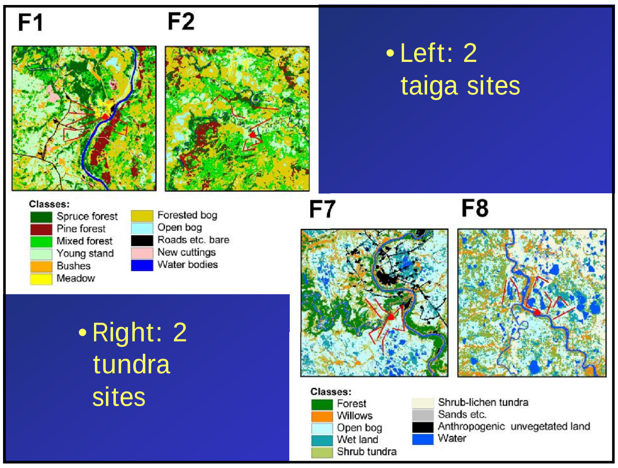
SPICE Research Area:





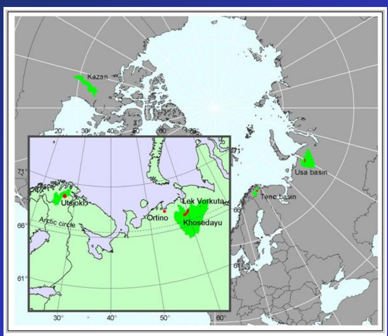
Aims of the project:

- The SPICE project has an integrated, problem-solving approach
- It answers a clear and immediate need of regional authorities for quality information regarding the state of society, economy and environment in the Pechora region
- The work is organised in 4 research themes with a total of 13 workpackages (wps); A) Economy and Society (3 wps), B) Terrestrial and Aquatic Pollution (4 wps), C) Indicators of Biodiversity (4 wps), and D) Impacts of Global Change (2 wps)
- An important integration/representation tool is the implementation of a geographic information system (GIS) for the study area
- Layers will include topography, vegetation and permafrost zones, detailed habitat classification of the fieldsites, the location of monitoring sites, and thematic layers related to environmental pollution, forest ecosystems and forestry, infrastructure, population, and industrial and rural economic sectors

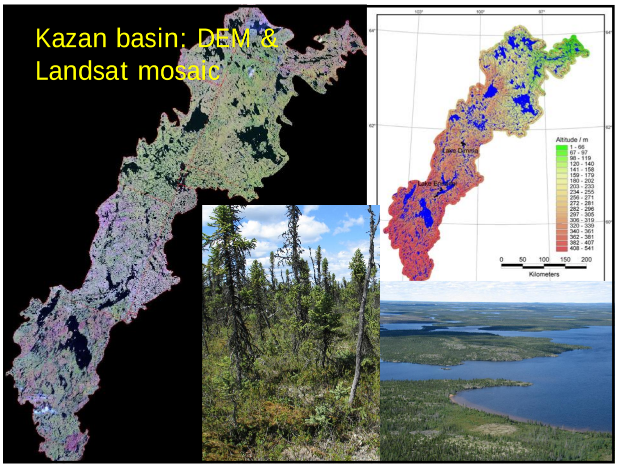


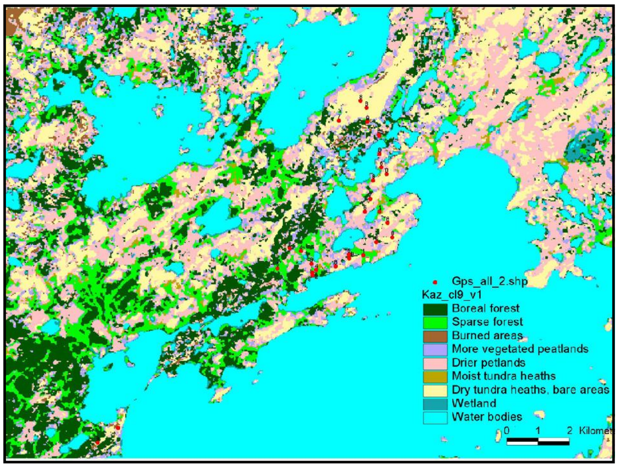
Global implications of Arctic climateprocesses and feedbacks - GLIMPSE

Research Areas:



http://www.awi-potsdam.de/www-pot/atmo/glimpse/index.html



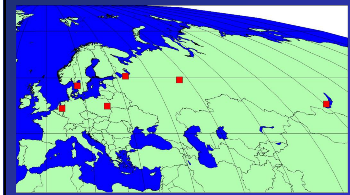


New EU-projects, 1:

E-Lup: Simulating land use processes - an interactive e-tool for sustainable impact assesment

- Started in January

http://www.helsinki.fi/bioscience/elup/



New EU-projects, 2:

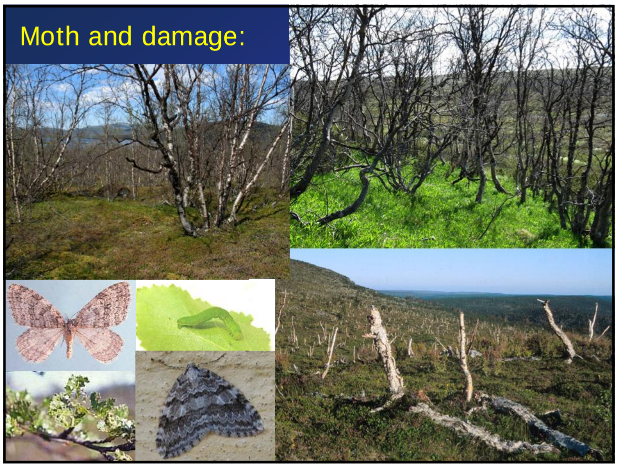
CARBO-North: Quantifying the carbon budget in Northern Russia: past, present and future

- New project, just starting

Example study from Ecology: Spatial distribution of the Autumnal moth outbreaks

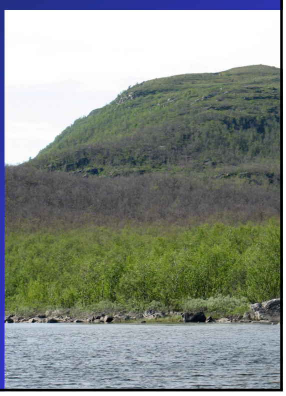
- Mountain birch *Betula pubescens* ssp. *czerepanovii* (former *tortuosa*) forms the forest-line forests in Fennoskandinavia
- Autumnal moth (tunturimittari), *Epirrita* (form. *Oporinia*) *autumnata,* causes perioidically large birch deaths
  - Sometimes also Winter moths (*Operophtera* spp.) causse outbraeks, but they have been occured only in more maritime climates
- Spatial distribution of these outbreaks is connected to topoclimatic factors

Moth and damage:



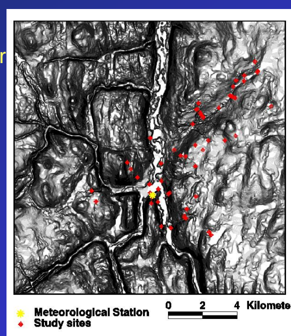
Egg mortality model for Autumnal moth

- Typivally Autumnal moth damage were not found in low-lying areas where cold air accumulates in winter
- This happens because low temperature caused death of eggs
- We developed GIS-based model for this phenomena:
  - Virtanen, T., Neuvonen, S. & Nikula, A. 1998. *Journal of Applied Ecology* 35: 311-322



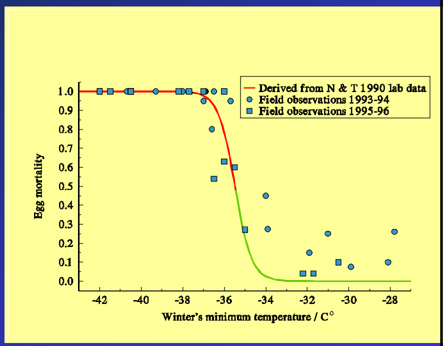
Egg mortality model for Autumnal moth, field study:

- We distributed eggs in different topographical positions, studied their winter suvival, and measured temperatures in same sites

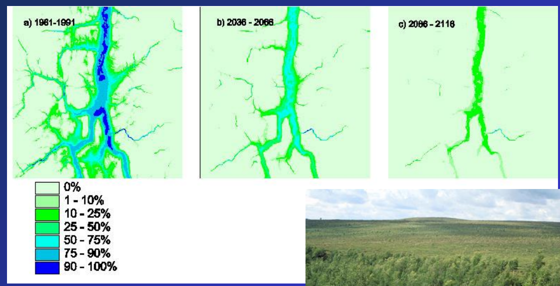


Egg mortality vs. minimum temperature of the winter:

Nilssen, A. & Tenow, O. 1990. Diapause, embryo growth and supercooling capacity of *Epirrita autumnata* eggs from northern Fennoscandia. *Entomol. Exp. Appl.* 57: 39-55



Predicted egg mortality probability in different climates, 1:



Predicted egg mortality probability in different climates, 2:

Predicted egg mortality in different climates in relation to a) vegetation types and b) elevation

a)

Years	Pine-forest	Birch/ Pine f.	Birch forest	Damage area	Tundra heath
1961-1991	56.5	36.1	15.0	6.3	2.6
2036-2066	24.6	12.7	5.3	1.5	0
2086-2116	7.1	3.5	1.5	0	0

b)

Years	<100	100-150	150-200	200-250	250-300	300-350	350-420
1961-1991	83.7	52.9	21.1	6.3	4.0	3.1	0.3
2036-2066	48.4	14.1	4.7	2.7	0.3	0	0
2086-2116	14.2	3.6	1.4	0.2	0	0	0