Satellite taxation of a forest inventory in the Boreal zone

PI 106

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ABSTRACT

The thematic map of the "vegetation complexes" has created for nature reserve "Kurgalsky" in framework of the joint project with Japan Aerospace Exploration Agency (JAXA). "Kurgalsky" located on the Kurgalian Peninsula of the Gulf of Finland (East Baltic Sea region). The reserve south-east bound is River Luga and Channel Rosson.

2001-2009 yrs remote sensing data from (Landsat (TM), SRTM, Terra (ASTER) and ALOS (AVNIR-2, PALSAR)) has been used for creating a inventory map. These data were integrated into GIS together with 1994-2009 yrs field floristic survey results and zoological observations.

Multi season satellite data were calibrated according timber amount by 2008-2009 yrs field expedition data. The forest productivity and forest fire damage were estimated on this base.

The relief of the examine area is a combination of the different level's tabular surfaces with ancient dunes and beach ridges as additional features. The leveling of this surface was related with Late Pleistocene and Holocene transgressions of Baltic Sea. The maximal biodiversity areas were islands of the highest level's post-glacial basins. This is concluded from the zonal and extrazonal vegetations ratio for the different level tabular surfaces.

***Keywords**:* Satellite data, forest inventory, forest fire, Kurgalian Peninsula, GIS, Holocene Baltic transgression.

1.INTRODUCTION

The nature reserve "Kurgalsky" is the base research subject. It located on the Kurgalian Peninsula of the Gulf of Finland (East Baltic Sea region). The reserve's south-east bound is River Luga and Channel Rosson. The landscape of the reserve corresponds with south boundary of Boreal zone. Most of widespread forest types at the investigated area are a fir, broad-leaved–fir and pine forests (the Southern Taiga Zone). Middle Europe broad-leaved black alder forests cover a small wetland area.

2.THE DATA, METHODS AND SOME RESULTS

Original objectives of PI 106 project are:

1. To revise and extend our database for test sites situated at the Kurgalian Peninsula (the North-Western region of Russia) for the accurate quantitative calibration of satellite data according timber amount.
2. To create satellite data base, which should include coefficients of spectral brightness (AVNIRI-2), DEM (PRISM), the effective area of radar backscattering (PALSAR) and vertical changes of the forest canopy surface (PALSAR – interferometry).
3. To estimate forest damages, caused by fire at the Kurgalian Peninsula in 2006.
4. To map the sanguivorous insects population density and related with that inoculable endemic risk.

Fig. 1. Observed maps. Red contour is the investigated area.

Successive steps were done for achieve results at the chief aims – forest species mapping and stand characteristics estimating:

Table 1 Field work observation data.

Source of data	Field work period	Content	Number of the observations
Komarov Botanic Iinstitute of RAS	1994-2001	Floristic description	646 (621)
Scientific Research Centre Ecology Safety of RAS	2008-2009	Floristic description and stand inventory characteristics.	100(76)
Zoological Institute of RAS	2005 - 2008	Time series of the mosquito activity	36

Table 2 Used satellite data

Satellite	Instrument	Mode, resolution, m/pixel	Date of survey
Landsat - 5	TM	30	12 August 2002
Landsat - 5	TM	30	22 April 2002
Terra	ASTER	15,30	29 June 2001
ALOS	AVNIR-2	10	10 July 2007
ALOS	AVNIR-2	10	10 May 2007
ALOS	AVNIR-2	10	25 March 2007
ALOS	AVNIR-2	10	26 June 2008
ALOS	PRISM	10	25 March 2007
ALOS	PRISM	10	28 May 2008
ALOS	PALSAR	FBS, 6.25	7 June 2006
ALOS	PALSAR	FBS, 6.25	23 July 2006
ALOS	PALSAR	FBS, 6.25	13January 2007
ALOS	PALSAR	FBS, 6.25	28 February 2007
ALOS	PALSAR	FBD, 12.5	2 August 2007
ALOS	PALSAR	FBD, 12.5	16 July 2007
ALOS	PALSAR	FBD, 12.5	17 September 2007
ALOS	PALSAR	FBD, 12.5	19 June 2008
ALOS	PALSAR	FBD, 12.5	18 July 2008
ALOS	PALSAR	FBD, 12.5	4 August 2008
ALOS	PALSAR	PLS, 12.5	21 May 2007
ALOS	PALSAR	PLS, 12.5	4 May 2007
ALOS	PALSAR	PLS, 12.5	4 November 2007
ALOS	PALSAR	PLS, 12.5	11 November 2007
Shuttle	SRTM	90	2000

1. The vegetation cover investigations were done by two expeditions in 2008 and 2009 years. Observations were made at the 100 test areas with size 10*10m each. 52 test sites among them are wood covered. The floristic description of these test sites were based on the Brown-Blance scale.

Komarov Botanical Institute of RAS took part in the project for the nature reserve “Kurgalsky” creation in 1994-2000 years. The vegetation map was created as result of this activity. This map and original observation data was used to plan the 2008-2009 yrs SRCES expeditions and to form the Training sites.

Zoological Institute of RAS has investigated a mosquito population on the Kurgalian Peninsula since 2005 year. A lot of observation periods were done at the first tens of the test sites. One of this activity aims is an investigation of the landscape variation of the mosquito population density.

2. Both satellite database (Tab. 2) and field work floristic data (Tab. 1) were integrated into GIS.

3. Field work point vegetation associations were syntaxonomically classified. For each forest association was defined the union, order, and class. The inventory map legend was compiled at the next step on the base of this syntaxonomy (Tab. 4). It was expanded taking into account fires aftereffects.

Training sites was formed by the field work observation database (176 samples). Each sample should have based on the one or more field work observation point. Thus association, union, order and class were defined syntaxonomically for each forest sample.

4. Data processing satellite imagery was carried out in several stages. In the first stage mapping was performed by maximum likelihood classification (MLC) over the complete set of available remote sensing characteristics. Each of the 176 samples was considered as an independent and formed their own MLC class. At the next stage the analysis of the spatial distribution of classes and their probabilities of "detection" and "false positives" were done. It result used to evaluate the possibility of separating or combining classes from training sites (on the base of satellite data). The result map legend and decode table (from MLC (sample) classes to legend classes) were compiled on the base of this analysis and MLC (sample) classes hierarchical syntaxonomy. This legend included 21 classes, with 14 vegetation classes (see legend on the fig. 3). The legend was expanded for the pine forests. It included several burned pine forest classes and pine forests of various solvency (bonitat) classes. The number of legend classes for the associations of coastal, meadow and marsh vegetation was on the contrary, reduced. Part of the samples was excluded from consideration as being too heterogeneous in their characteristics of the surface. In the next step the newly formed training sample was used for the maximum likelihood classification and formed the next version of the inventory map (Fig 3).

5. The remote sensing characteristics self-descriptiveness (on the base of interclass variance) was analyzed to prepare the attribute space for classification.

The effective area of radar backscattering (on FBD PALSAR mode) was considered as an important tool for Boreal zone forest inventory (Fig 2). Some Boreal zone forest objects recognition becomes more confident with radar data using. For example the probabilities of detection increase and false alarm decrease with EARBS adding to attribute space, especially for recognize bogs (HV-EARBS) (Tab 3), after fire dead stand or flooded forest (HH-EARBS) (Fig 2).

For the optical device data well known that near infrared band is more informative for vegetation, then visible. Because this multiple NIR data (AVNIR-2 band 4) was used for MLC together with one or two time visible (AVNIR-2 band 1-3)

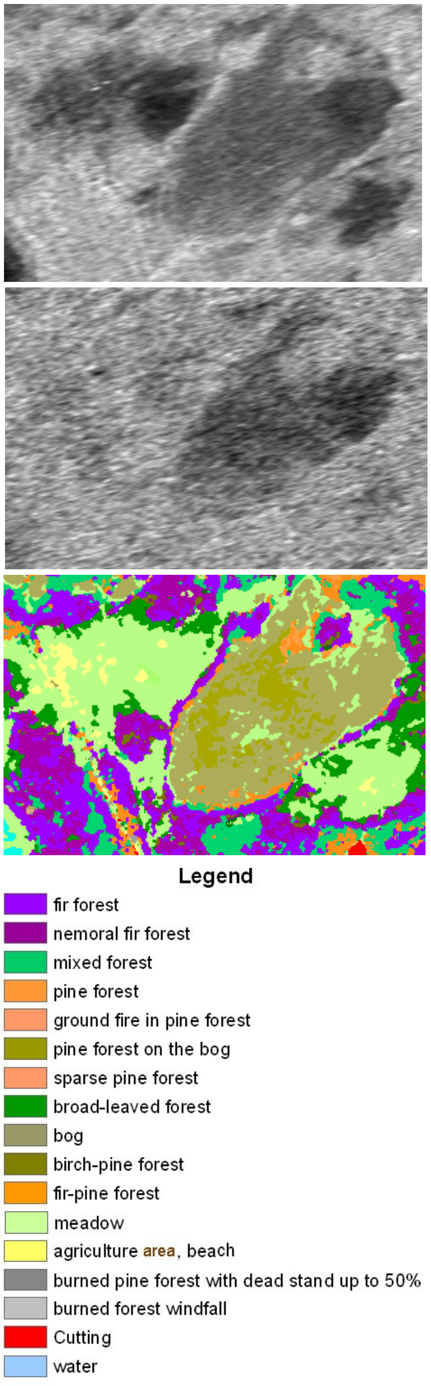
Forest stands parameter correlations with EABS (the best in Fig 11) can be used to understanding the radar data opportunities in the forest inventory.

Table 3 The results of Kurgalian reserve forest inventory by MLC. The training sites probabilities of detection and false positives (α-error).

Inventory class	AVNIR data		PALSAR (FBD) & AVNIR data	
	Detect	α-Error	Detect	α-Error
spruce forests	0.62	0.43	0.66	0.39
nemoral spruce forests	0.65	0.24	0.73	0.22
pine forests	0.82	0.19	0.82	0.17
sparse pine forests	0.89	0.43	0.92	0.34
spruce-pine forests	0.68	0.41	0.71	0.39
birch-pine forests	0.58	0.21	0.63	0.20
mixed swamped forests	0.75	0.42	0.79	0.36
broad-leaved forests	0.92	0.20	0.93	0.15
pine on the bog	0.88	0.09	0.90	0.08
bog	0.88	0.02	0.90	0.02
meadow	0.99	0.06	1.00	0.04
agricultural areas, beaches	0.92	0.02	0.95	0.01
coastal	1.00	0.02	1.00	0.01
burned pine forests	0.92	0.12	0.93	0.10
Flooded forests	1.00	0.01	1.00	0.00
dead stands pine forests	0.90	0.05	0.95	0.03
burned forests windfall	0.69	0.03	0.74	0.03
cutting	1.00	0.00	1.00	0.00

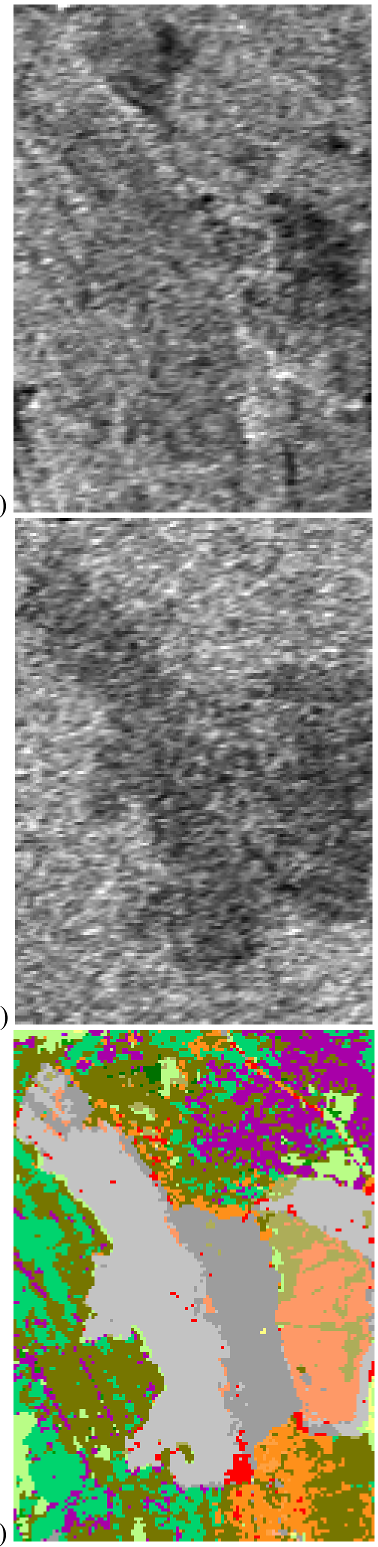
Table 4.Basic vegetation associations of the nature reserve "Kurgalsky" (AO = associations of order)

Complex	Basic plant associations	
	latin	english
1	2	3
nemoral spruce forests	***Rhodobryo rosei – Piceetum abietis*** Korotkov 1986	spruce nemoral herbs and mosses of *Bryales* forests
	Querco-Piceetum abietis (W.Mat.1952) W.Mat. et M.Pol. 1955	nemoral spruce forests with oaks
	Melico nutantis-Piceetum abietis (Caj.1921) K.-Lund 1962	spruce nemoral herbs forests
pine forests	***Cladonio arbusculae-Pinetum*** (Caj.1921) K.-Lund 1967	dry pine lichen forests
	Oxycco quadripetali-Pinetum K.-Lund 1981	pine sphagnum forests
spruce-pine forests	***Vaccinium vitis-idaea-Pinetum boreale*** Caj.1921	pine greenmoss forests
spruce forests	***Eu-Piceetum abietis*** (Caj.1921) K.-Lund 1962	demutation of spruce greenmoss forests
	Melico nutantis-Piceetum abietis (Caj.1921) K.-Lund 1962	demutation of spruce nemoral herbs forests
Birch-pine forests	***Oxycocco quadripetali-Pinetum*** K.-Lund 1981	Birch-pine swampy sphagnum forests
Mixed swamped forests	***Vaccinio uliginosi–Piceetum*** Tx. 1955	Birch-pine-spruce swampy sphagnum forests
broad-leaved forests	***Ficario-Ulmetum*** Knapp ex Medw.-Korn. 1952	floodplain elm forests
	Aceri campestris-Tilietum cordatae Zaugolniova, Braslavskaia, 2003	multi dominant broad-leaved forests with *Allium ursinum*
	Querco roboris-Tilietum cordatae Laivinsh 1986 ex Laivinsh in Solomesč et al. 1993	coastal oak forests
	Carici elongatae-Alnetum medioeuropaeum (Koch 1926) Tx. et Bodeux 1955	floodplain black alder forests
	derivate forests	birch, aspen, grey alder forests
herbal vegetation	AO ***Molinietalia*** W.Koch 1926	moist meadows
	AO ***Arrhenatheretalia*** R.Tx. 1931	mesophilous meadows
	AO ***Cakiletalia maritimae*** R.Tx. et Oberd. 1946	vegetation of marine coast
	AO ***Ammophiletalia*** Br.-Bl.(1931) 1933	vegetation of marine sand and dune
	AO ***Agropyretalia repentis*** Oberd., Th.Muller et Gors in Oberd. et al. 1967	pre-meadows
	AO ***Artemisietalia vulgaris*** Lohm. in Tx. 1947	ruderal associations
	agrophytocenoses	agricultural vegetation
Coastal vegetation	AO ***Phragmitetalia*** Koch 1926	large hygrophytes-helophytes
	AO ***Magnocaricetalia*** Pignatti 1953	communities of large sedges
Pine forests on the bog	***Vaccinietea uliginosi***, with position between ***Vaccinio-Piceetea*** and ***Oxycocco-Sphagnetea.***	undersized pine dwarf scrub-sphagnum forests on the bog
bog vegetation	AO ***Scheuchzerietalia palustris*** Nordhagen 1937	small sedge-moss mesotrophic bogs
	AO ***Sphagnetalia magellanici*** Kastner et Flossner 1933	oligotrophic and oligotrophic-mesotrophic bogs
	AO ***Caricetalia fuscae*** Koch 1926 em. Br.-Bl. 1949	sedge-herb-moss bogs



(a) (b) (c) (d)

Fig 2A Kurgalian reserve. The FBD PALSAR mode effective areas of radar backscattering for some open (meadow, bog) and forest covered landscapes of the investigated area. The complex data image was calculated from effective areas of radar backscattering on HH mode (real part) and HV-mode (imaginary part). Fig 2A(a) is showing the amplitude of this image (backscattering signal amplitude) and fig 2A(b) is showing the phase (backscattering signal "polarization degree"). Fig 2A(c) is a part of the investigated area inventory map (Fig 3) and (d) is fragment legend.



(a) (b) (c)

Fig 2B Kurgalian reserve. The FBD PALSAR mode effective areas of radar backscattering for the separation of the forest after fire and forest covered areas. For the legend see fig 2A.

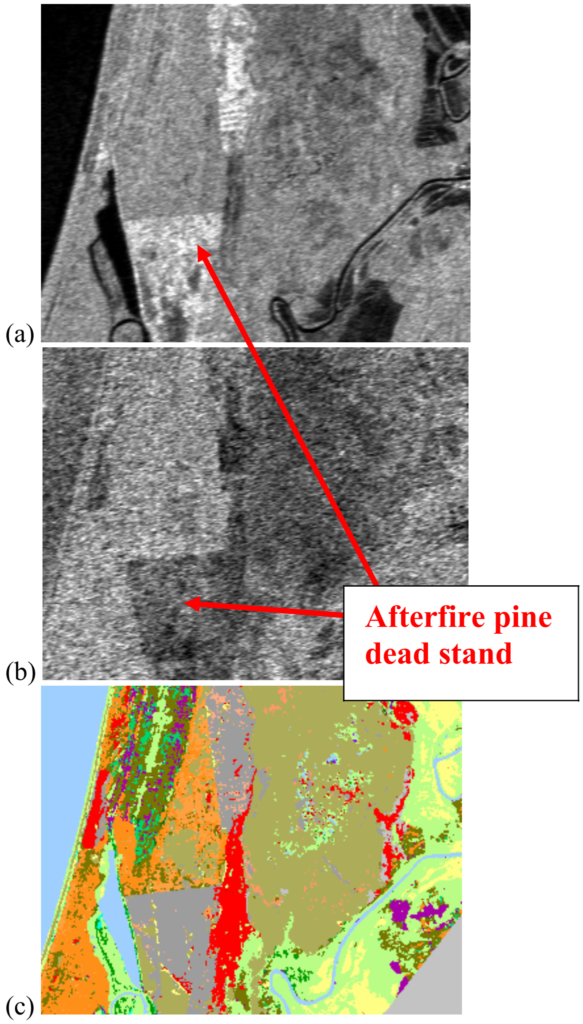


Fig 2C Kurgalian reserve. The FBD PALSAR mode effective areas of radar backscattering for the separation of the forest covered and dead stand forest after fire areas. For the legend see fig 2A. The dead stand is working as corner reflector. The high level of the effective areas of radar backscattering in HH mode were been showing for dead stand forest after fire.

6. When the training sites and attribute space were formed the final version of the thematic inventory map was created by MLC with using the decode table, compiled on previous stage. The quality of this map can be estimated by probabilities of detection and false positives (Tab 3). The inventory map verification was carried out based on actual points of surface observations (Table 5). At the end the map has been segmented (Fig 3).

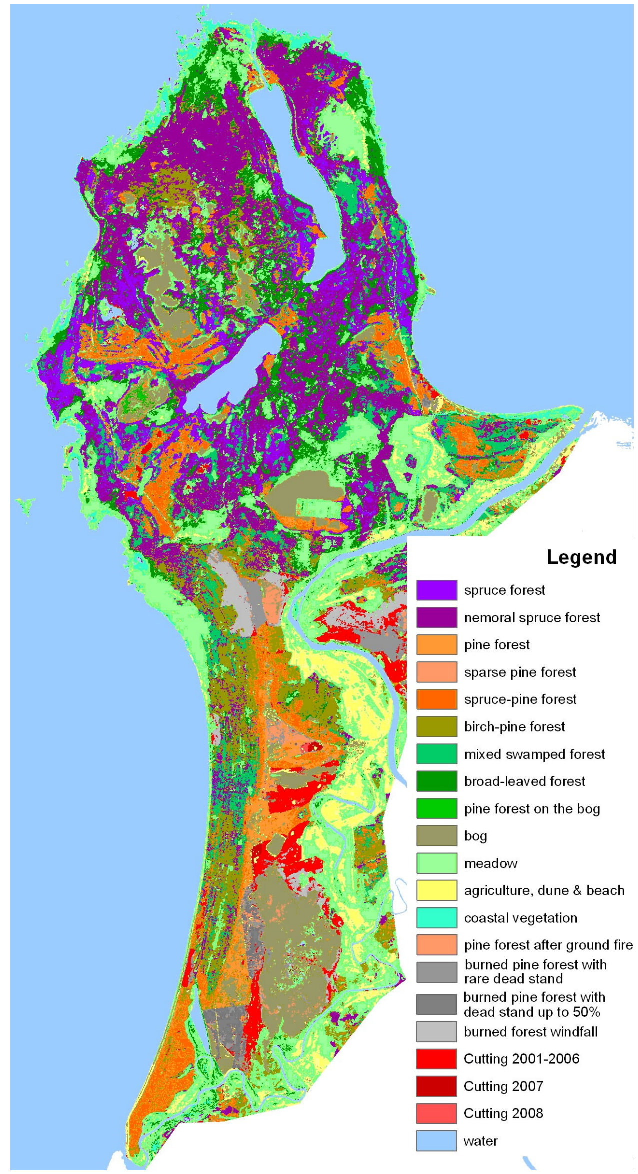


Fig. 3. The Kurgalian reserve inventory map created by MLC on the base of satellite data.

Table 5. Verification of the some inventory classes of Kurgalian reserve by actual data (point to point) — the probabilities of detection and false positives (α-error).

Inventory classes	Detect	α-Error	Number of points
spruce forests	0.31	0.53	8
nemoral spruce forests	0.68	0.41	14
meadow	0.94	0.00	8
birch-spruce forests	0.06	0.80	9
pine forests	0.45	0.04	29
black alder forests	0.72	0.30	20
dead stand pine forests	0.93	0.00	7
burned forests	0.86	0.12	7
cutting	1.00	0.13	7

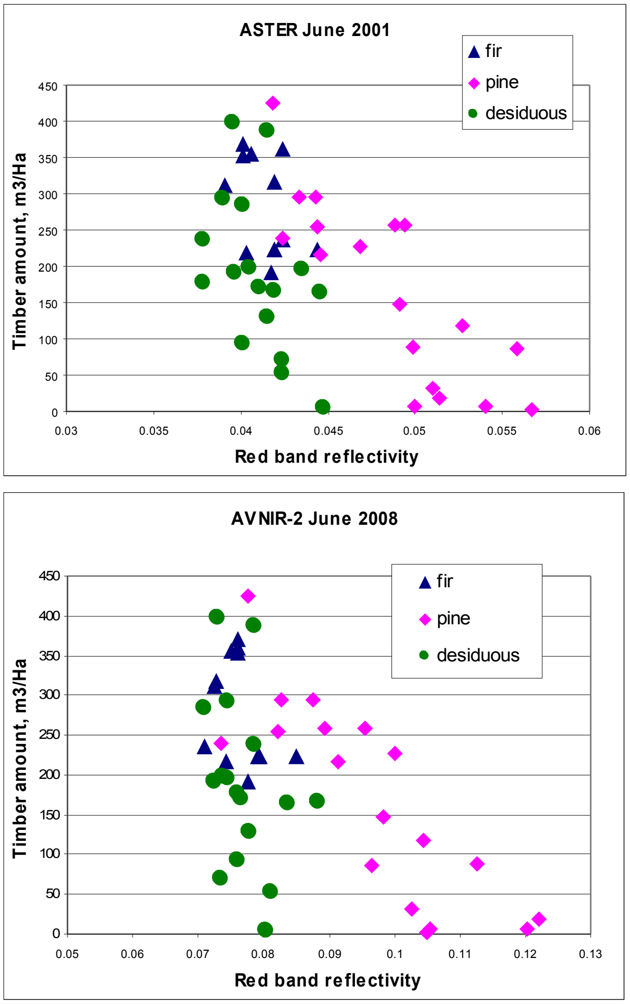


Fig 4. The correlation satellite red band reflectance from ASTER (June 2001) and ALOS-AVNIR-2 (July 2007) with timber amount by field work observation data.

7. The multiple regression between timber amount and reflectance in visible and near infrared bands (Fig. 4) was created. The timber amount was estimated for the 70 test sites from tree number, diameters and heights. The average regression error estimation was 50 m3/Ha.

8. The timber amount maps was created for three periods (June 2001, July 2007 and June 2008). The average forest productivity for every forest map classes was estimated on the next step (Tab.6).

9. Serious forest fires were detected in August 2006 on investigated area (Fig 6). Fire damage (Tab. 7) and after fire activity (Tab. 8) was been estimated on the base of inventory map (Fig 3) and map of the forest productivity for periods before and after the fire. Additionally the error of the integrated productivity estimation was evaluated by table 7 as 10-12 m3/Ha.

Table 6. Forest productivity estimation.

	Area, Ha	Productivity, m3/Ha
Spruce forest	6889	260
Pine forest	416	94
Pine forest after background fire	94	22
Pine forest at the bog	29	20
Sparse pine forest	89	56
Mixed coniferous	2280	138
Mixed forest	4281	167
Deciduous	2000	130
Meadow, agriculture	1481	7

Fig. 5 Forest fire on August 7 2006 on the Kurgalian reserve. Terra (RGB by 2-2-1 MODIS band), Lansat-5 (RGB by 6-5-3 TM band)

Table 7 Fire damage estimation on the base of 2001 year forest productivity data (in 2006 prices).

	Area,Ha	Forest productivity, m3/Ha	Timber amount m3	Price, mln. $
After fire forest cutting	1092	96	104797	8.0
After fire stands	924	91	83803	6.2

Table 8 Cutting area productivity estimation.

Area	Productivity (m3/Ha) on the base of data for		
	2001	2007	2008
Cutting 2001-2006	123	15	10
Cutting 2007	79	25	14
Cutting 2008	70	60	6

10. PALSAR – interferometry was not an effective method for investigating of the time variation of canopy height. The cause is low signal – noise ratio (low coherency), that on the one hand related with taiga canopy architecture and on other hand not good survey condition.

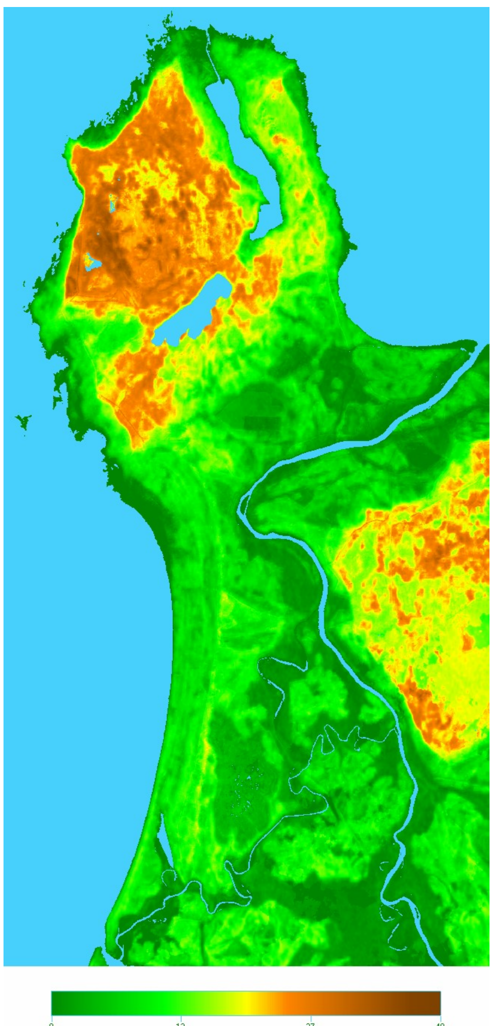


Fig. 6 SRTM DEM of the Kurgalian reserve after canopy height correction.

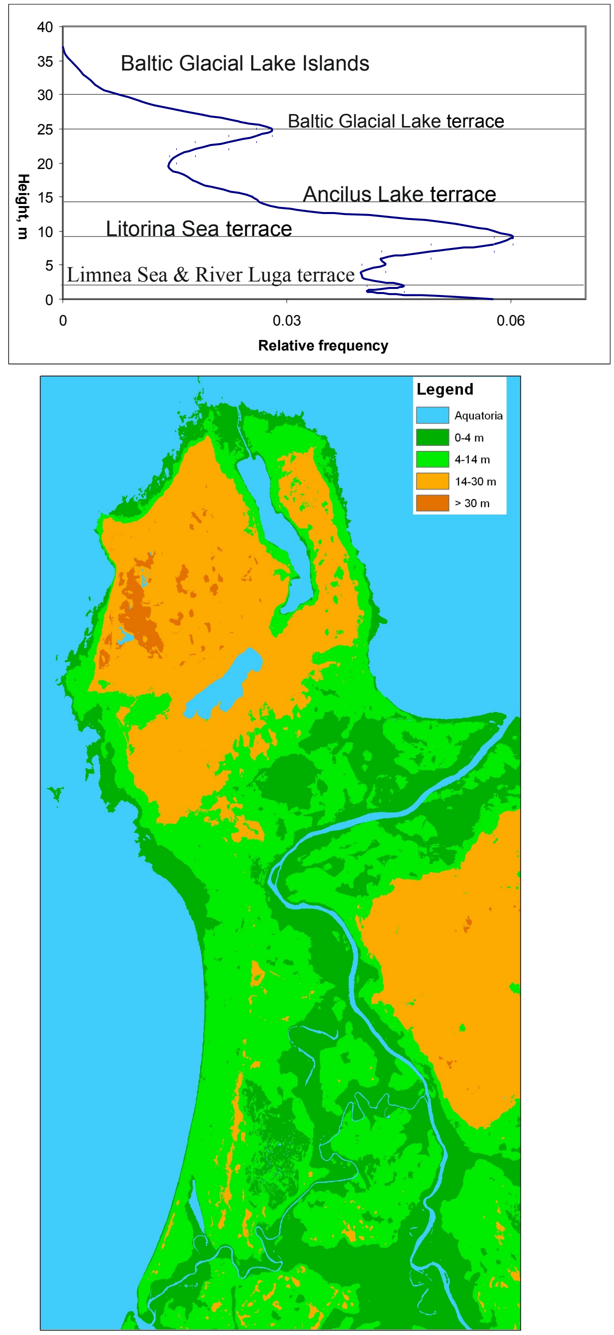


Fig. 7. Altitude distribution. The definition of the accumulative terraces levels and terraces spatial position.

11. The spatial variation of the mosquito activity is complexly masked by it's time variation, that are changing from one species to another. In this part of the project objectivities are no resuts.

3.DISCUSION

One of the significant tasks of landscape mapping is relief analysis. Digital Elevation Model (DEM) by SRTM was used for this task. This DEM's altitude corresponds to the canopy altitude in the first approximation. This problem was solved by using forest inventory. Forest stand heights

at 70 observation points, ASTER data, SRTM altitude and topography map have been used to generate new DEM (Fig. 6). The average estimation of the retrieved DEM's altitude errors has amounted as 5 m.
The simple topography analysis based on the heights histogram allows recognizing some tabular surface on Kurgalsky Peninsula. These surfaces levels are corresponded with accumulative terrace levels, known in this region as Holocene Baltic transgression result [1] [2] [3] (Fig 7).

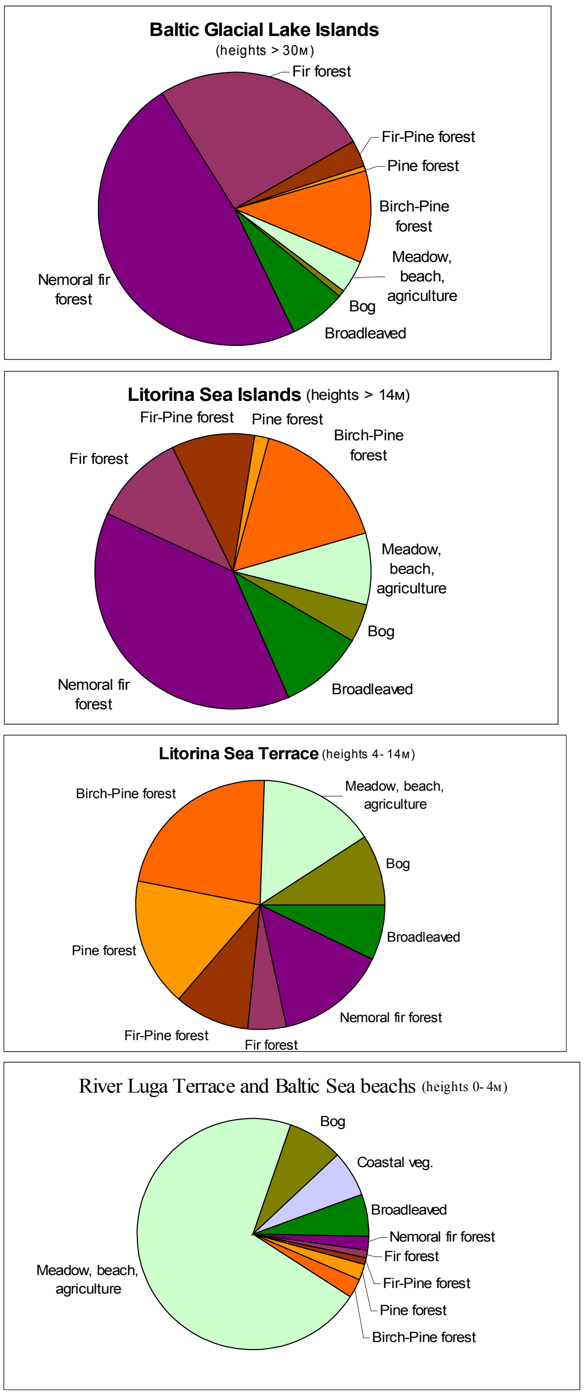
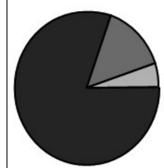
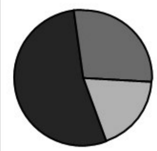
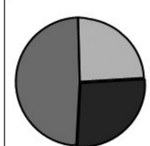
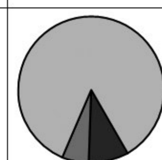


Fig. 8. Inventory class ratio for different height levels.

Table 9. Vegetation features of different height level areas.

Heights Levels	Vegetation	Area ratio for zonal, extrazonal & intrazonal vegetation	Rare associations
Baltic Glacial Lake Islands (heights > 30 m)	extrazonal, hemiboreal		*Rhodobryo rosei – Piceetum abietis; Carici elongatae-Alnetum medioeuropaeum*
Litorina Sea Islands (heights > 14 m)	extrazonal, hemiboreal, with nemoral influence		*Rhodobryo rosei – Piceetum abietis; Ficario-Ulmetum; Aceri campestris-Tilietum cordatae; Carici elongatae-Alnetum medioeuropaeum*
Litorina Sea Terrace (heights 4-14 m)	zonal, boreal		*Carici elongatae-Alnetum medioeuropaeum*
Limnea Sea & River Luga terraces, (heights 0 - 4 m)	intrazonal		*Querco roboris-Tilietum cordatae Carici elongatae-Alnetum medioeuropaeum*

The inventory class ratios were created for different terrace levels. The significant differences of the taxonomic diversity are shown in Fig. 8. Higher level areas have a greater part of the extrazonal vegetation (Tab.9). This feature of the investigated area can be explained by the conservation of the thermophilic plants since Holocene climatic optimum.
Checking the inventory technology and hypothesis of thermophilic plants conservation since Holocene climatic optimum was performed on the example of the nature reserve "Berezovye Islands". It is located on the Berezovye Island archipelago in the north-eastern Gulf of Finland, 70 km north of the Peninsula Kurgalsky (Fig.1). Most of the archipelago is covered by south taiga forests. To create a training sites was used vegetation map of the archipelago scale 1:50000 [4]. 96 samples was used to generate the inventory map.

Table 10. The results of Berezovye Island archipelago forest inventory by MLC. Training sites probabilities of detection and false positives (α-error). Broad class version.

Inventory classes	Detection	α-Error
Spruce bilberry-greenmoss	0.82	0.44
Spruce sphagnum	0.66	0.74
Spruce-pine bilberry-greenmoss	0.41	0.27
Pine dwarfshrub-greenmoss	0.25	0.14
Pine herb-bilberry-greenmoss	0.65	0.41
Birch-pine herb-bilberry-greenmoss	0.45	0.82
Pine bracken-reedgrass-bilberry	0.36	0.67
Pine grassy	0.78	0.57
Birch-pine bilberry-horse tail-sphag-num	0.40	0.69
Birch-pine bilberry-sphagnum	0.39	0.85
Birch-pine dwarfshrub-sphagnum	0.22	0.81
Birch bilberry-herb	0.59	0.38
Birch grassy	0.78	0.69
Birch tussockgrassy	0.66	0.19
Birch hygrophytic herb	0.14	0.60
Birch hygrophytic herb-sphagnum	0.62	0.59
Black alder-birch horse tail-sphagnum	0.58	0.77
Black alder forbs	0.48	0.51
Black alder	0.80	0.54
Black alder ferny	0.80	0.56
Black alder hygrophytic herb, sedge	0.72	0.68
Bog heath-crowberry-sphagnum	0.96	0.06
Bog pine-heath-dwarfshrub-sphagnum	0.95	0.02
Bog reed-sphagnum	0.97	0.01
Upland meadow multigrass	0.72	0.24
Upland meadow foxtail	0.77	0.39
Upland meadow tussockgrassy	0.78	0.47
Reedy	1.00	0.07
Settlement	0.99	0.06
Young pine heats-lichen-greenmoss	0.40	0.85
Young birch and sparse old pine	0.61	0.34
Sparse old pine willowtea-reedgrass	0.38	0.51

The last version map (Fig 10) have better class probabilities (Tab 10).

Very detailed archipelago vegetation map legend [4] has allows to evaluate the possibility of vegetation associations recognition by satellite data. Most associations except the reedy, bog and settlement are not well recognized (Tab. 10). Therefore, must be used broader group of plant communities hierarchical classification - unions, orders, classes, when inventory making by satellite data. As well as to nature reserve "Kurgalsky" the union of the map classes was carried out, which improved the quality of classification (Tab. 10,11)

Table 11 The results of Berezovye Island archipelago forest inventory by MLC. The inventory map classes probabilities of detection and false positives (α-error).

Inventory map classes	Detect	α-Error
Spruce greenmoss forest	0.90	0.46
Spruce-pine greenmoss forest	0.41	0.27
Pine greenmoss forest	0.72	0.10
Birch-pine sphagnum forest	0.53	0.75
Young birch and sparse old pine	0.56	0.36
Birch grassy forest	0.89	0.09
Black alder forbs	0.67	0.52
Pine-dwarfshrub-sphagnum bog	0.97	0.02
Upland meadow	0.91	0.18
Reedy	1.00	0.07
Settlement	0.99	0.06

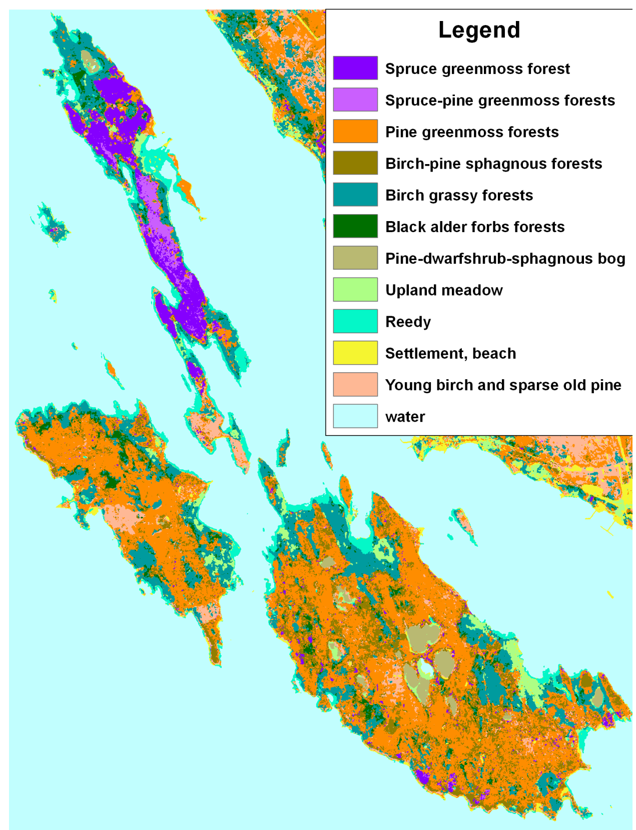


Fig. 10. The inventory map of Berezovye Island archipelago created by MLC on the base of ALOS data.

The hypothesis of broad-leaved forest origin was testing on the base of Berezovye Island inventory map and ASTER DEM. Four tabular level surfaces was recognizing by altitude histogram analysis. The heights of this surfaces well agrees with archeology data in this area:

29 m level – Ancilus Lake maximum, 16 m – Litorina Sea maximum (about 7500 yrs BP), 11m – second Litiorina Sea maximum (about 5500 yrs BP) and 4 m – Limnea Sea maximum [3] [5]. But vegetation shows reverse zoning in comparison with the reserve "Kurgalsky" – extrazonal vegetation fraction decrease with height.

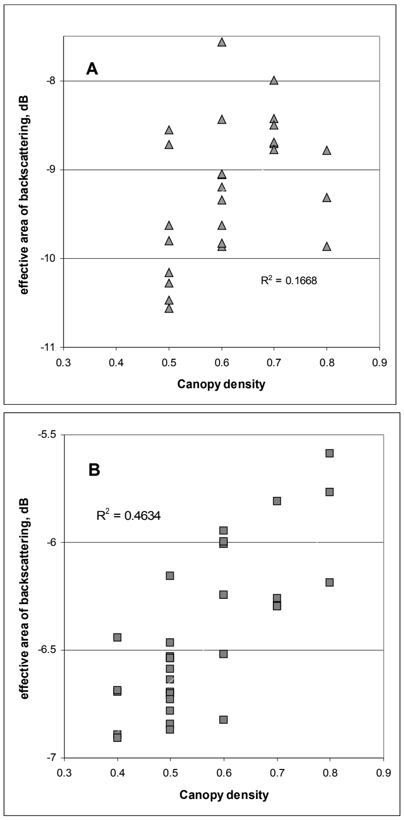


Fig. 11. Canopy density of the Berezovye Island archipelago forests and effective area of backscattering. Points correspond to the average EABS for each site. Dry and cold spring (22-04-09), deciduous forests (A). Dry and warm autumn (4-10-09), coniferous forests (B)

The reason for the difficulties lies in the interclass heterogeneity of reflective features associated with the heterogeneity of canopy architecture and ground cover vegetation community. The first factor correlated with the crown architecture (stand species), stand (canopy) density and forest's age and solvency (bonitat) (tree height & diameter). Its influence can be estimate by the second factor eliminating, that is possible by using the spring survey data (Fig. 4, Fig. 12, Fig. 11 A). It is difficult to estimate the impact of the ground cover vegetation community on quality final classification. Experience has shown that two type widespread ground cover in taiga are green moss and sphagnum, that have different reflective features. Therefore some "vegetation complexes" have close spectral characteristics, for example spruce sphagnum and pine green moss or pine sphagnum and birch bilberry-green moss.

Table 12 Comparison of inventory classes probabilities for various content of the attribute space

Union vegetation classes	AVNIR multiple data		AVNIR & PALSAR (FBD) multiple data		PALSAR (FBD) multiple data	
	Detect	α-Error	Detect	α-Error	Detect	α-Error
spruce forests	0.94	0.51	0.95	0.35	0.41	0.73
pine forests	0.52	0.07	0.67	0.05	0.46	0.21
decidous forests	0.83	0.18	0.86	0.15	0.58	0.62
bog	0.93	0.55	0.95	0.07	0.69	0.55
coastal vegetation	0.91	0.25	0.97	0.21	0.92	0.22
coniferuous forests	0.74	0.03	0.79	0.03	0.72	0.11
settlement	0.97	0.06	0.90	0.11	0.55	0.77

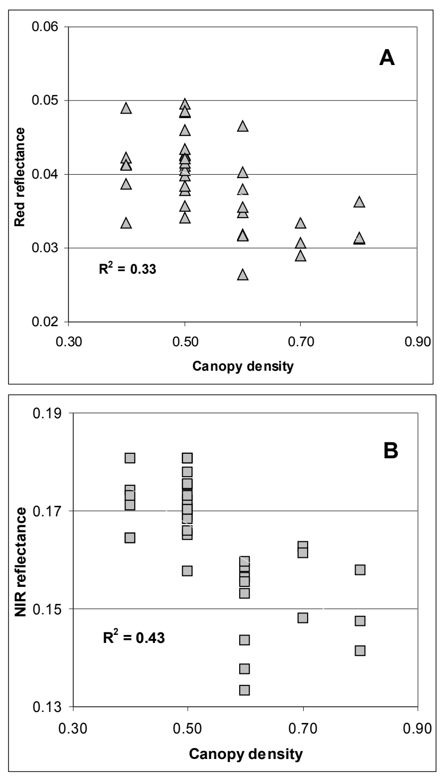


Fig. 12. Correlation between Berezovye Island coniferous forest canopy density and reflectance in Red (A) & NIR (B) ALOS bands. Points correspond to the average for each site reflectance. Survey 25 03 2007.

4.CONCLUSION

1. The boreal zone forest inventory by ALOS data need include two stages. The first have be forest species mapping and the second – timber supply and another forest features estimating.
2. Both stages require a lot of field work observations. The measurement methods should be used to evaluation forest stand parameters.
3. Best inventory mapping results are achieved when using simplest map legend which included spruce, pine and deciduous forests, bogs and meadows. A fractional division of the forest communities leads to increase α-errors (probability of false positives) and β-errors (probability of false negatives)
4. ALOS data allow estimating forest stand parameters, such as timber amount and forest stand height. The best evaluation can be expected at a sufficiently variable sampling, well provided a field work observation for each forest vegetation class.
5. Forest stand height estimations can be used for SRTM's or PRISM's DEM correction.
6. PALSAR (FBD) data is useful for recognize bog and another open area and can be use for identifying dead forest stand and flooded forests.
7. The quality of inventory map increase, when multi time AVNIR-2 data were supplemented by multi time PALSAR (FBD) data (Tab. 4,12).
8. Forest inventory map created by ALOS data can be used for investigate biological diversity in boreal zone.

5. ACKNOWLEDGMENT

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