



# Efforts to improve the National Forest Inventory in Poland

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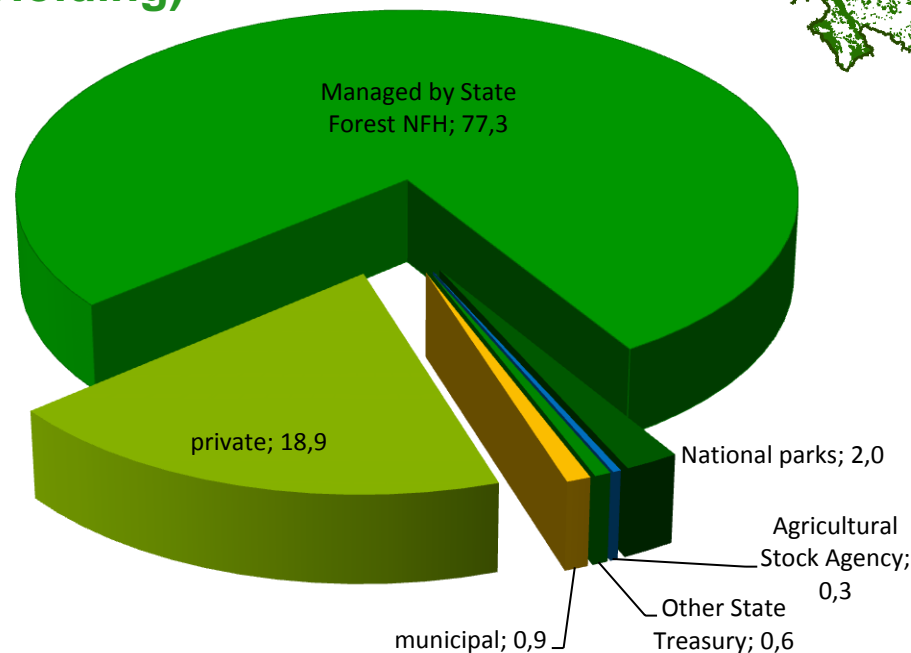
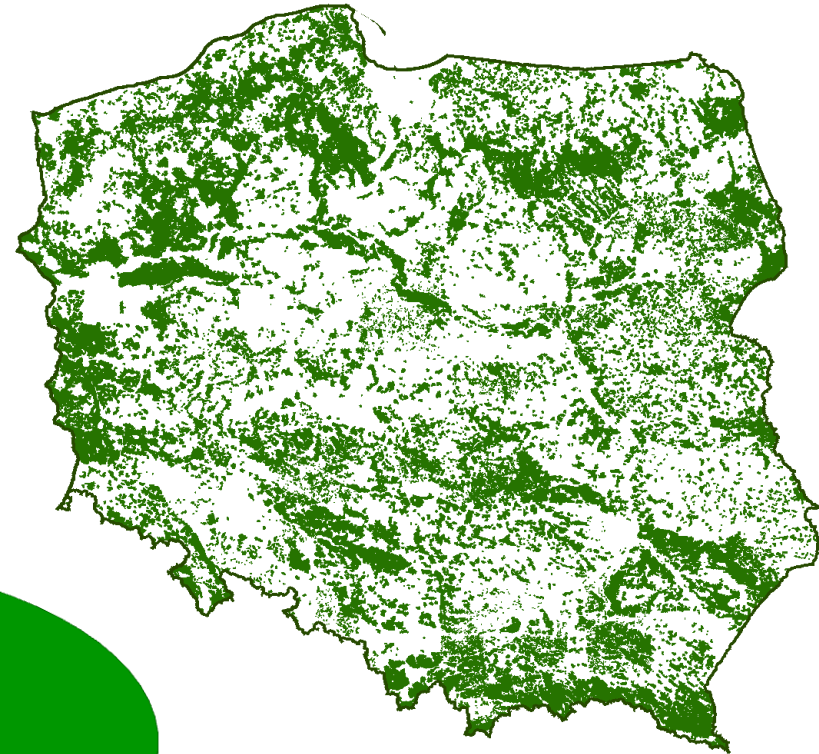


## Forests in Poland

**Forest cover: 29,2%, 9.3 million ha**

**Growing stock: 2,47 billion m<sup>3</sup>**

**Most of the forests are public property, of which almost 7.6 million ha is managed by a single public organization (State Forests National Forest Holding)**





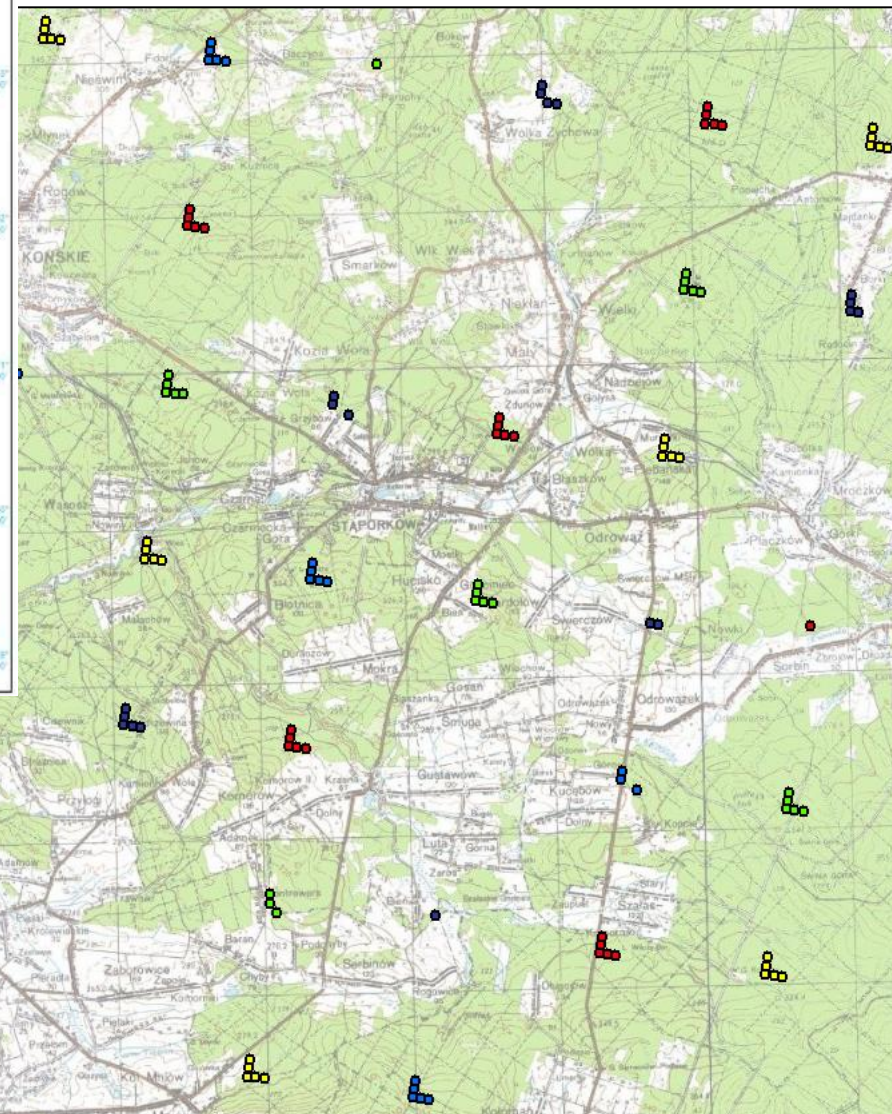
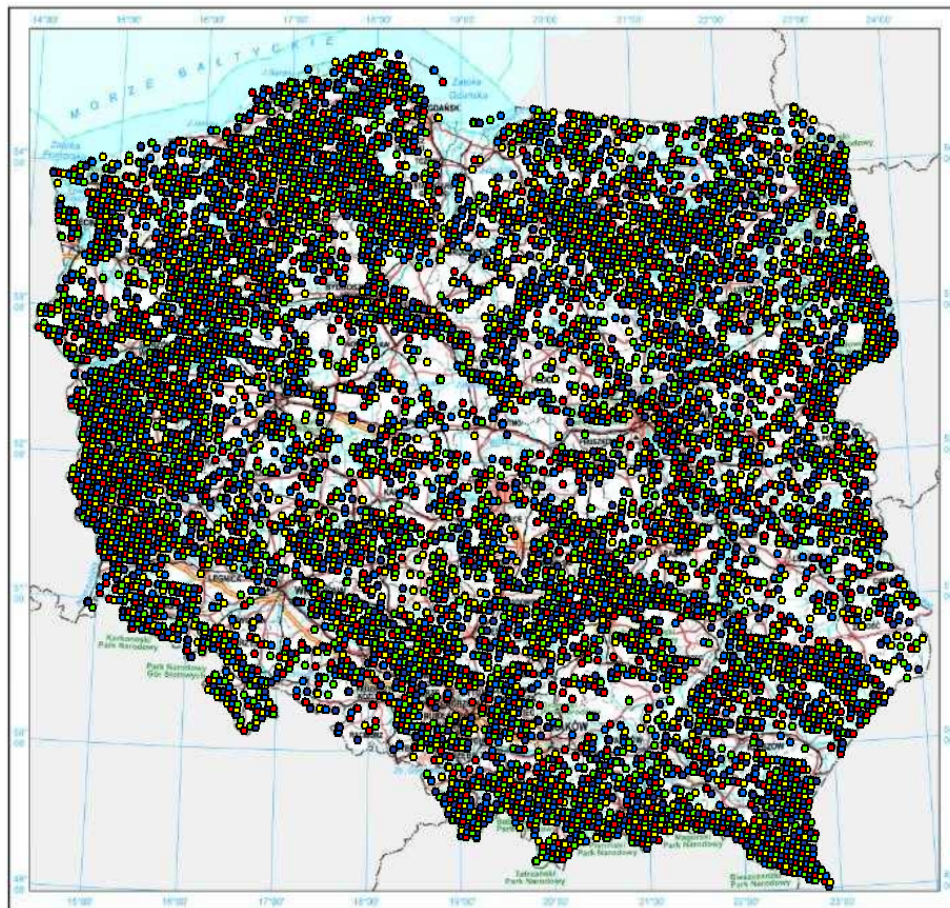
# Polish NFI design

## Sampling design

Sample plots are located in a regular grid. The ICP-Forest monitoring Level I grid (EEC 1987) was used as a 16x16 km wireframe, which was then divided into a 4x4 km grid. Nodes of the 4x4 km grid are the NFI primary points.



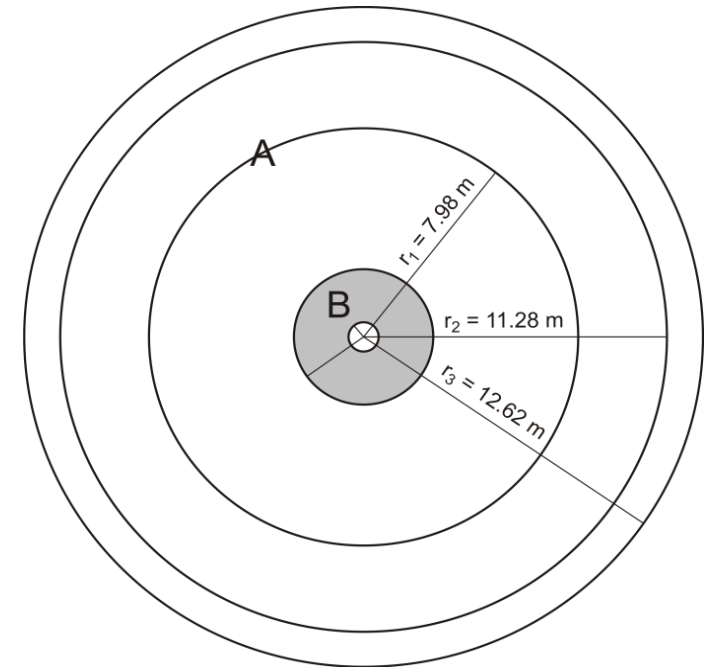
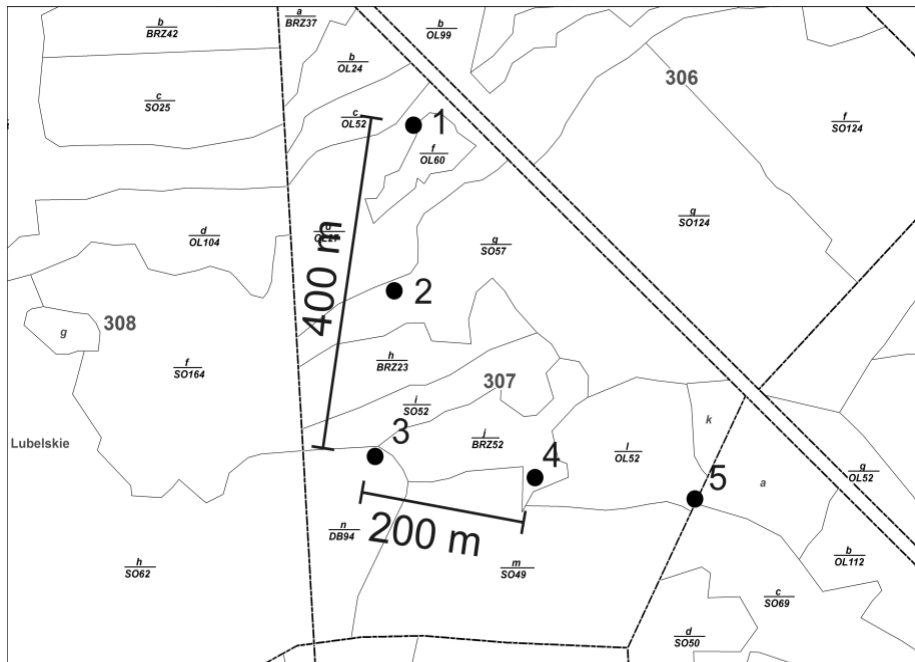
The NFI is designed for continuous inventory. The inventory cycle length is 5 years, which means that yearly measurements and observations are carried out on 20% of all sample plots spread throughout the country. There are no gaps between cycles.



- **2005-2014:** only plots on a forested land according to the cadastral register
- > 28,000 plots
- **From 2015:** all forests



## Sample plot design



The radius of each subplot used to be dependent on the age and vertical structure of this particular portion of the stand.

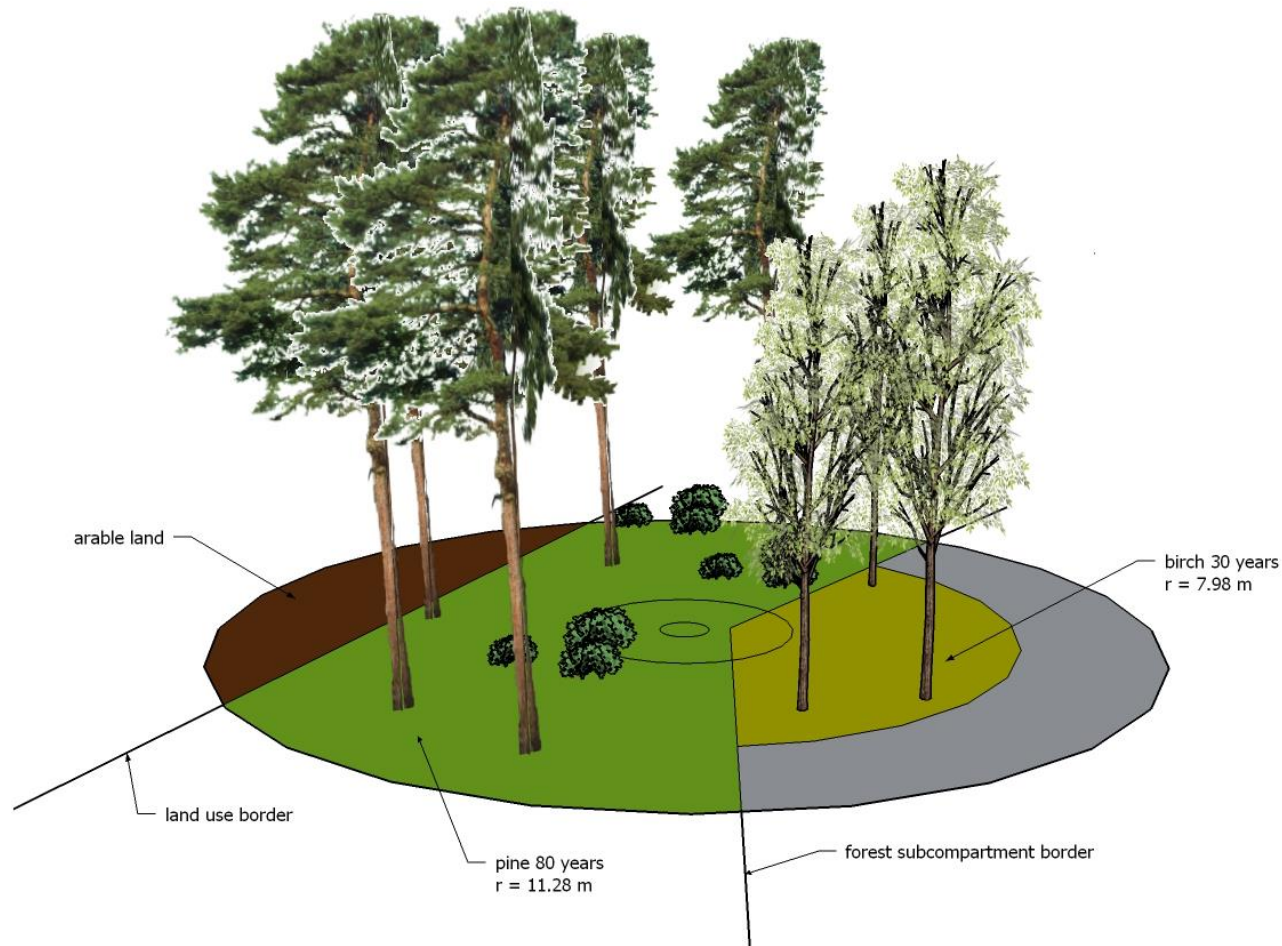
Stand features	Plot A area [m <sup>2</sup> ]	Plot A radius [m]
1. Age between 1 and 60 years or unforested land	200	7.98 ( $r_1$ )
2. Age over 60 years	400	11.28 ( $r_2$ )
3. Regeneration phase	500	12.62 ( $r_3$ )

**From 2015 all plots have an area of 400 m<sup>2</sup> ( $r = 11.28$  m).**



## Sample plot design

If an administrative division boundary, a boundary between different forms of land ownership, a land use boundary or a stand subcompartment boundary, falls within the plot, the plot is divided into subplots.





# Sample plot documentation

**DOKUMENT ŹRÓDŁOWY** 98 149 513 Strona 1 z 3

**CECHY ADRESOWE**  
Współrzędne wyliczone: szerokość [52.365845] długość [22.849899]  
Nr pow. [98 149 513] Nr jedn. [1] Nr kierow. [24] Miroslaw Murawski Data [2012-08-02]  
Rozp. [07:22] Zak. [09:05] Nr wg LP [1 18]  
Wojew. Powiat Gmina  
[20] podlaskie [10] siemiatycki [92] Siemiatycze-gmina wiejska  
Krajna [4] MAZOWIECKO-PODLASKA

**POW. PRÓBNE**  
Własność [5] Rodz. uz. gr. [80] Rodzaj pow. [1] Cecha d-stanu [8] Typ d-stanu [ ]  
Gat.pan. [SO] Wiek gat.pan. [66] Bonit. [0] Zadrzew. [ ] Zwarcie [1] Bud.pion. [1]  
Zasł. gosp. na pow. [9] Uzak. i nasilenie [26 90] Stan siedl. [4]  
Forma terenu [12] Położenie terenu [13] Wystawy i nachylenia [6 10]  
Typ siedl. lasu [ ] Sposób okresl. tśl. [3] Stan siedl. [ ] Korekta tśl. [12] Zmiana wielk. pow. [2]  
Drzewa o wysokości do 0,5 m Drzewa o wysokości powyżej 0,5 m i pierśnicy do 3 cm Drzewa o pierśnicy od 3 do 7 cm  
Gat.pan. [ ] Zadrzew. [0] Gat.pan. [ ] Zadrzew. [0] Gat.pan. [ ] Zadrzew. [0]

**DRZEWOSTAN**  
Rodz.pow. [1] Funkcja lasu [3] Forma ochr.przr. [3] Rodz.ochr. [ ] Natura 2000 [3] Kat.ochr. [ ]  
Spos.zag. [1] Gat.pan. [SO] Wiek gat.pan. [66] Zad.poddz. [8] Zw.poddz. [3] Bud.pion.poddz. [1]  
Sposób opisu d-stanu [3]

**UWAGI**  
Deformacje, rany po okrzesywaniu

**POWIERZCHNIA B** Nachylenie [10] Promień cm: [259] Pow. m²: [9]  
Nr pow. [98 149 513] Pokrywa [2 100] Pokrycie cał. [%] [ ]

**Dane o drzewach i krzewach o pierśnicy do 70mm**

Lp	Gatunek	War.	Pokrycie [%]	H [m]	Uszkodzenie
1	IKRU		+	0,2	

Drzewa i krzewy o wysokości 0,5 m i większej i pierśnicy do 30 mm

Lp	Gatunek	War.	N	H [m]	Uszkodzenie

Drzewa i krzewy o pierśnicy większej lub równej 30 mm i mniejszej od 70 mm

Lp	Gatunek	War.	N	H [m]	Uszkodzenie

**Pniaki określane na powierzchni B**

Lp	Gatunek	Zm	Azymut	L [cm]	D [mm]	Roz.	L. porz. drzewa

**POWIERZCHNIA A** Numery drzew zastab. [27 1 11] Numery pniaków zastab. [ ]  
Pokrywa dla pow.A [2 90 4 10] Nachyl. [10] Promień cm: [1131] Pow. m²: [182]

General information about the sample (sub)plot

**DOKUMENT ŹRÓDŁOWY** 98 149 513 Strona 2 z 3

**Dane o drzewach o pierśnicy od 70 mm**

Lp	Gat.	Wiek	War.	Pień	Zm	A	L [cm]	D12 [mm]	D13 [mm]	H [m]	Uszkodz.1	Uszkodz.2
1	SO	66	1	0	1	268			184		5 3 30	13 6 30
41	SO	66	1	5	5	1054			230		13 4 10	
2	SO	85	1	0	12	585			317		20	
3	SO	40	2	0	13	366			105		6 6	11 9 90
4	SO	66	1	0	14	420			248		13 4 30	
5	SO	66	1	0	17	763			142		12 9 90	13 6 30
6	SO	66	1	0	18	622			131		13 6 30	11 9 50
7	SO	66			3	30	661					
9	SO	66	1	0	30	571			146		11 9 40	
8	SO	40			3	30	800					
10	SO	66	1	0	35	869			255		13 5 30	
12	SO	66	1	0	37	439			153		13 4 30	
11	SO	85	1	0	38	246			357		13 4 40	
13	SO	66	1	0	38	511			166	16,0	13 4 20	
14	SO	66	1	0	40	635			303		2 7	
16	SO	85	1	0	42	698			337		2 7	
15	SO	40	2	0	43	335			100	7,5	13 5 50	11 9 50
17	SO	66	1	0	45	820			224		13 5 30	
18	SO	66			3	51	825					
19	SO	85	1	19	0	53	1090		336		2 3	
21	SO	66	1	0	56	741			239		13 4 50	
20	SO	66			19	3	57	1093				
22	SO	66	1	0	62	394			155		2 2	13 4 30
25	SO	85	1	0	70	1040			380		20	
23	SO	66	1	0	70	615			244		2 3	
24	SO	40			3	72	1093					
26	SO	85			4	74	1128					
27	SO	85	1	0	98	316			330	16,0	2 2	13 3 30
28	SO	85	1	28	0	98	839		435		2 3	13 3 30
30	SO	85	1	28	0	101	820		290		13 3 30	
29	SO	85	1	28	0	102	885		284		13 3 30	
36	SO	66	1	0	335	1030			211		13 3 20	
35	SO	85	1	0	336	535			322	17,5	5 3 40	13 3 20
37	SO	66	1	0	341	690			208		5 3 20	13 3 10
38	SO	40	2	0	347	548			89	6,5	13 3 30	11 9 50
39	SO	40			3	354	717					
40	SO	66	1	0	355	667			178		13 6 20	

**Drzewa martwe**

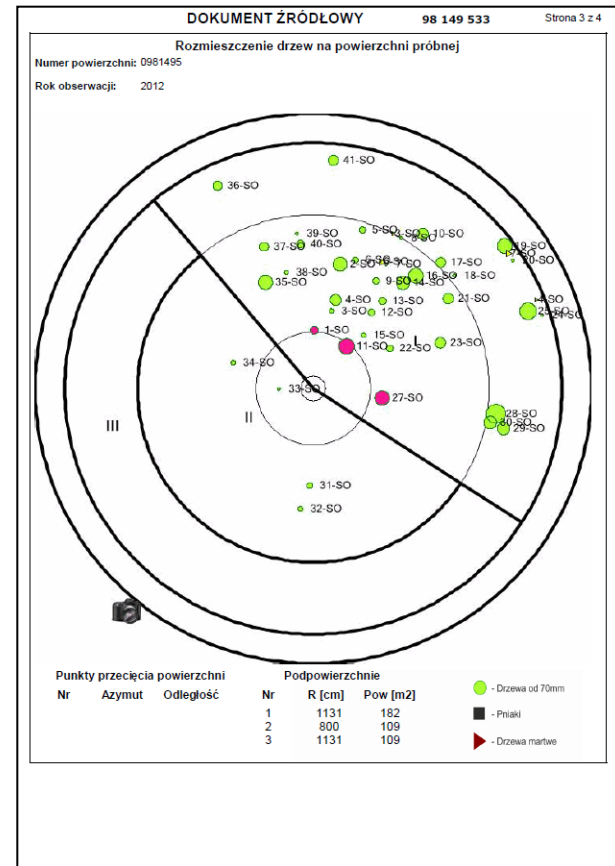
Lp	Gat.	Zm	Ac	L [cm]	Aw	D12 [mm]	D13 [mm]	HL	Roz.	Typ	Lp pniaka drzewa
3	SO	0	27	800	0			106	7,0	2 4	8
6	SO	1	28	661	0			182	14,5	1 4	7
1	SO	2	51	825	0						18
7	SO	0	55	1093	0			169	10,0	2 4	20
4	SO	0	68	1093	0			95	7,5	2 4	24
5	SO	2	354	717	0						39

**Pniaki określane na powierzchni A**

Lp	Gat.	Zm	Azymut	L [cm]	D [mm]	Roz.	L. porz. drzewa

Imię i nazwisko wykonawcy: Miroslaw Murawski  
Podpis: .....

Description of all standing trees (alive and dead), dead wood, stumps within the (sub)plot



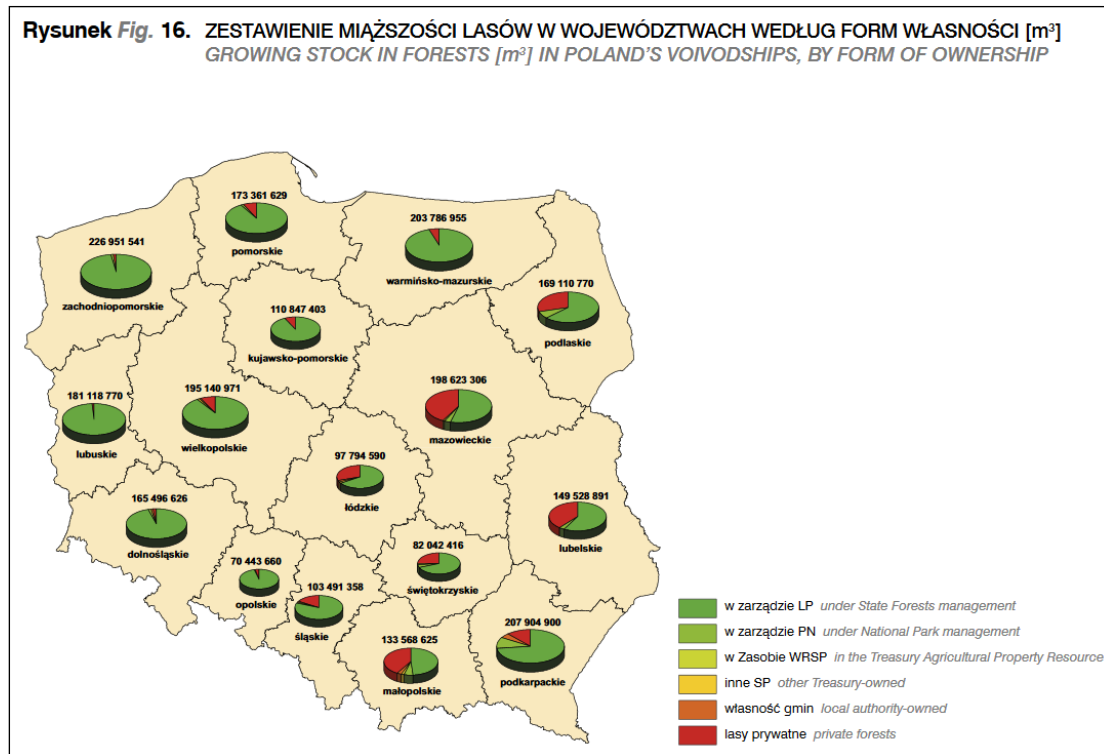
Sample plot layout sketch



## Polish NFI design

### Analysis

- annual reports
- over 80 different types of reports
- stock volume is calculated using the same tree volume estimation method as for forest management plans





## Polish NFI design

### Aggregation units

- Areas resulting from the intersection of the divisions of the country:
  - voivodships (provinces),
  - regional directoriates of the State Forests,
  - natural regions,
  - ownership categories.
- These units allow for easy aggregation of data for larger units.
- Results are presented for the following forest ownership categories:
  - State Forests,
  - National Parks,
  - State Treasury agricultural stock,
  - State Treasury other,
  - municipal,
  - private.





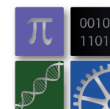
## Issues addressed

1. **Sample representativeness**
2. **Sample plot size**
3. **Sampling design**





# 1. Sample representativeness



Centrum

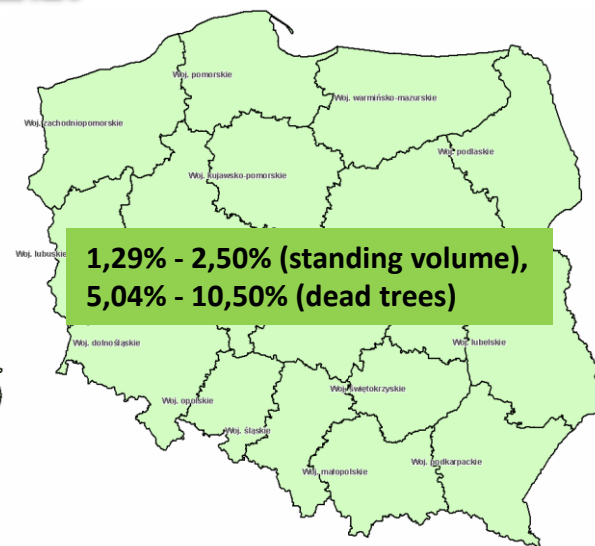
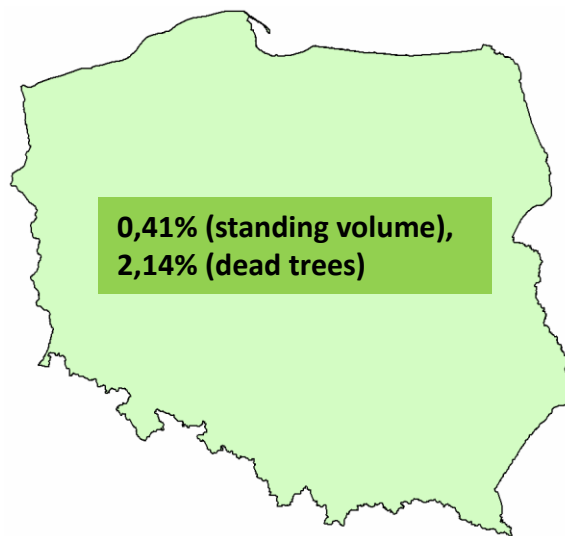
ZASTOSOWAŃ MATEMATYKI I INŻYNIERII SYSTEMÓW

"We solve problems"

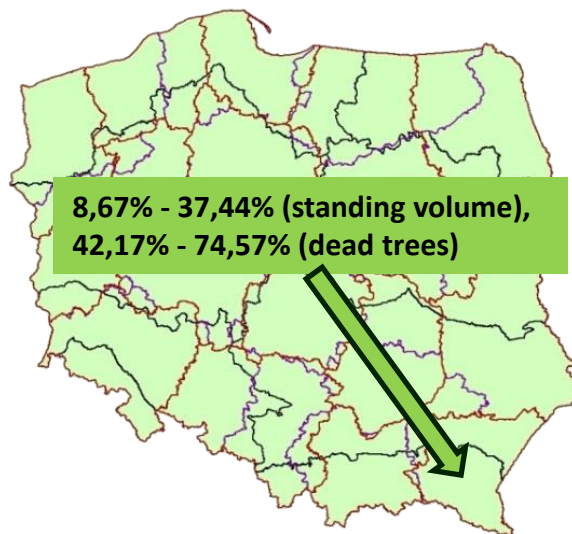
Total sample size is almost 30 000 sample plots

This is a lot but...

- reports are made for large and small subsets



Percent error (data 2006-2012)



- relative sample size in each age class:  
0,8400; 3,950; 6,3500; 2,2525; 2,7550; 4,000; 4,2250; 1,0000

- coefficient of variation :  
17,33% - 43,86% (standing volume), 84,34% - 138,84% (dead trees)

$$V = \frac{s}{\bar{x}}, \quad \bar{x} \neq 0$$

- There are still many more internal divisions of the sample...
  - species, damage classes, health condition classes, stump decomposition degrees, site types etc....

Carpathian region / Podkarpackie Province  
/ Regional State Forests Directorate Krosno  
/ municipal forests



# 1. Sample representativeness



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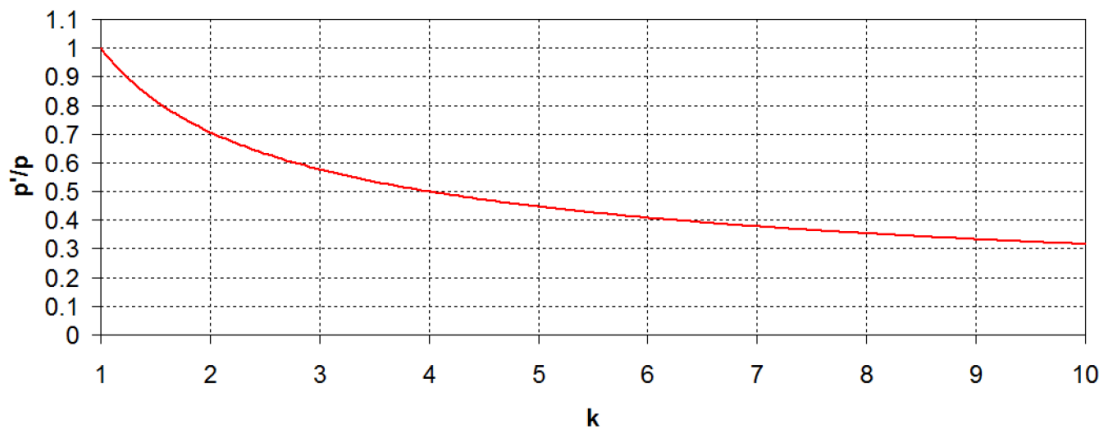
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## Possible solutions

- Increase the sample size by random sampling
- Use stratified sampling for rare phenomena
  - E.g. some ownership categories are underrepresented (their total area is very small) so it would be advisable to get additional samples in these categories
- Increase number of plots and/or their size

$$p_{kd} = \frac{p}{\sqrt{k \cdot d}}$$



*For uncorrelated forest:*

*p – percent error*

*k – plot number increase factor*

*d – plot size increase factor*

- Get rid of aggregation units and calculate all high level units in one step





## 2. Sample plot size

- In the Polish NFI1 and NFI2 plots were of variable size:
  - The radius of each subplot is dependent on the age and vertical structure of this particular portion of the stand.

Stand features	Plot A area [m <sup>2</sup> ]	Plot A radius [m]
1. Age between 1 and 60 years or unforested land	200	7.98 ( $r_1$ )
2. Age over 60 years	400	11.28 ( $r_2$ )
3. Regeneration phase	500	12.62 ( $r_3$ )

- Problems with formulating estimators
- From 2015 all plots have an area of 400 m<sup>2</sup> ( $r = 11.28$  m).







### 3. Sampling design



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## Local resemblance (correlation)

- Local resemblance index ( $\lambda$ ) = probability that at a 200-m distance of a forested area there is also a forested area
- For uncorrelated forest:



$$\lambda = T = \frac{Z - 1}{A - 1}$$

$Z$  – number of forested nodes  
 $A$  – number of all nodes



### 3. Sampling design



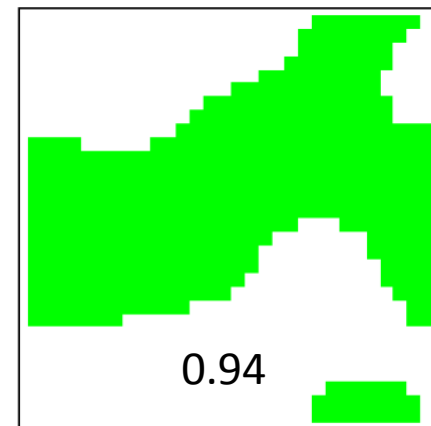
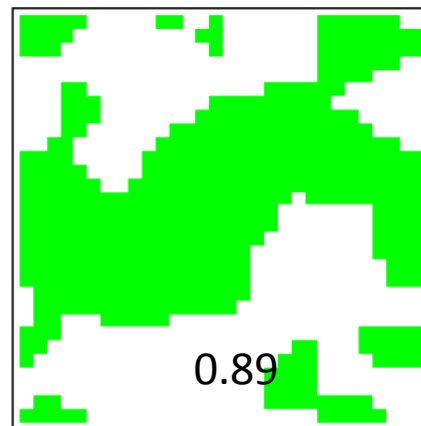
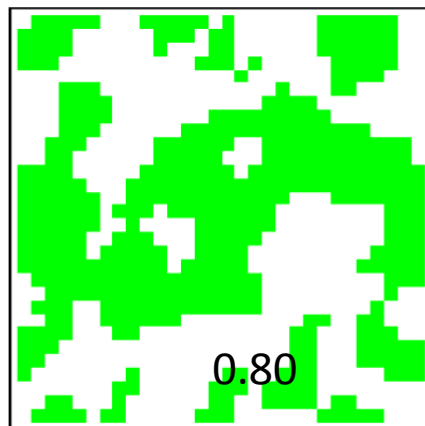
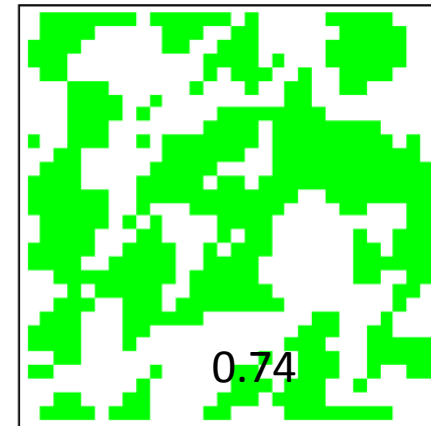
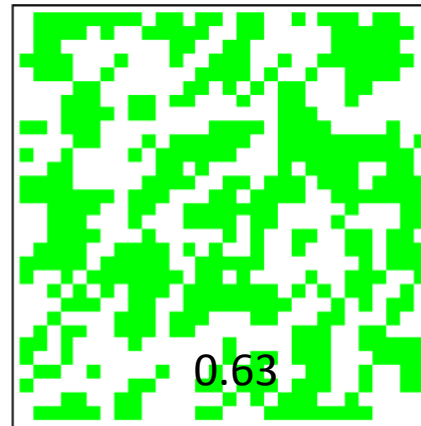
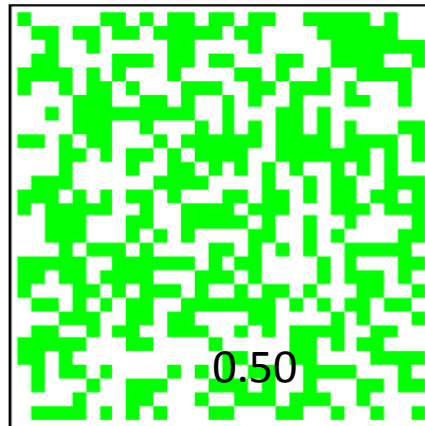
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## Local resemblance (correlation)

- Artificially generated „forests”





### 3. Sampling design



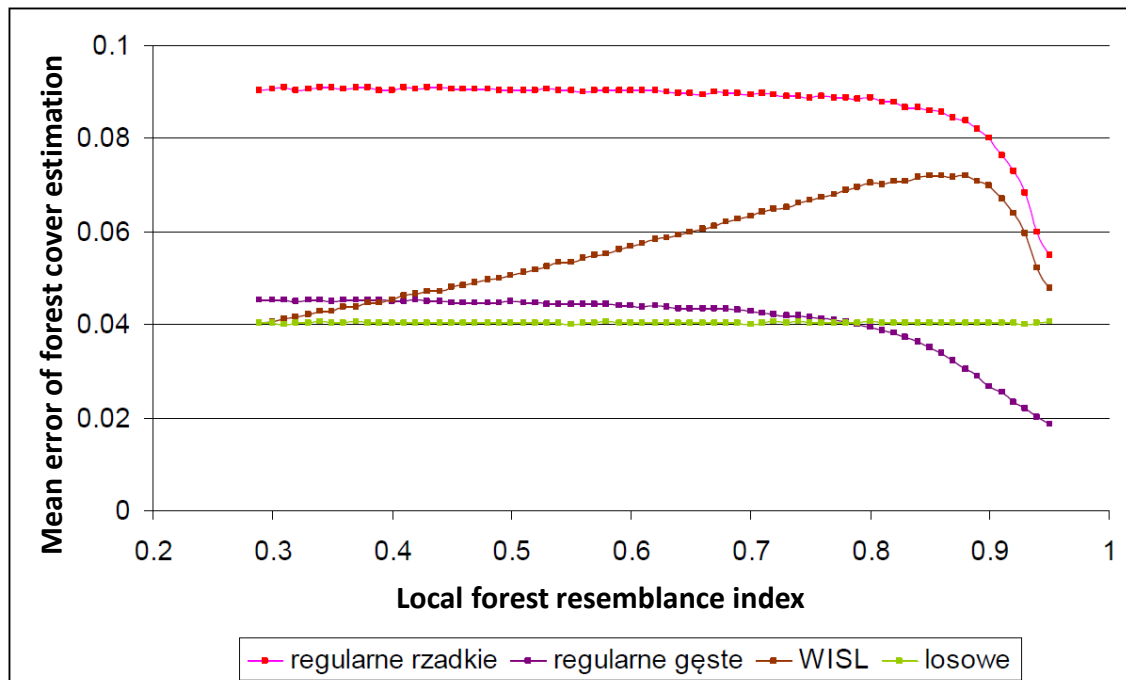
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## Sampling design vs. error

- Empirical error estimation (16 km x 16 km)



1. Thin network (4x4 km) – 25 plots
2. Dense network (2x2 km) – 100 plots
3. NFI (4x4 km, clusters) – 125 plots
4. Random – 125 plots

1.                      2.                      3.                      4.



### 3. Sampling design



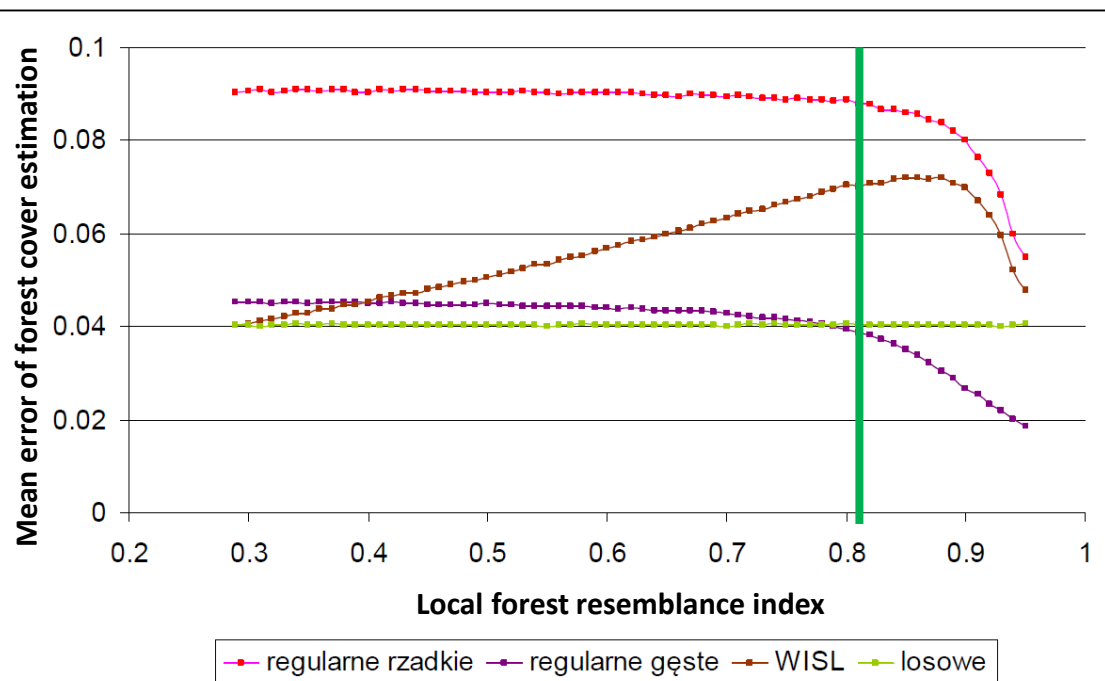
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## What is the real local resemblance factor for Polish forests?

- Forest cover: 29.2%
- Raster analysis based on real data
- Local resemblance index (empirical): **0.81**



### Conclusions:

- Clustering 4x4 km improves accuracy as compared to single point 4x4 km
- Cluster is probably too compact



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