Long-term forestry studies on permanent sample plots *vs* Field-Map technology. How to deal with different spatial coordinate systems?

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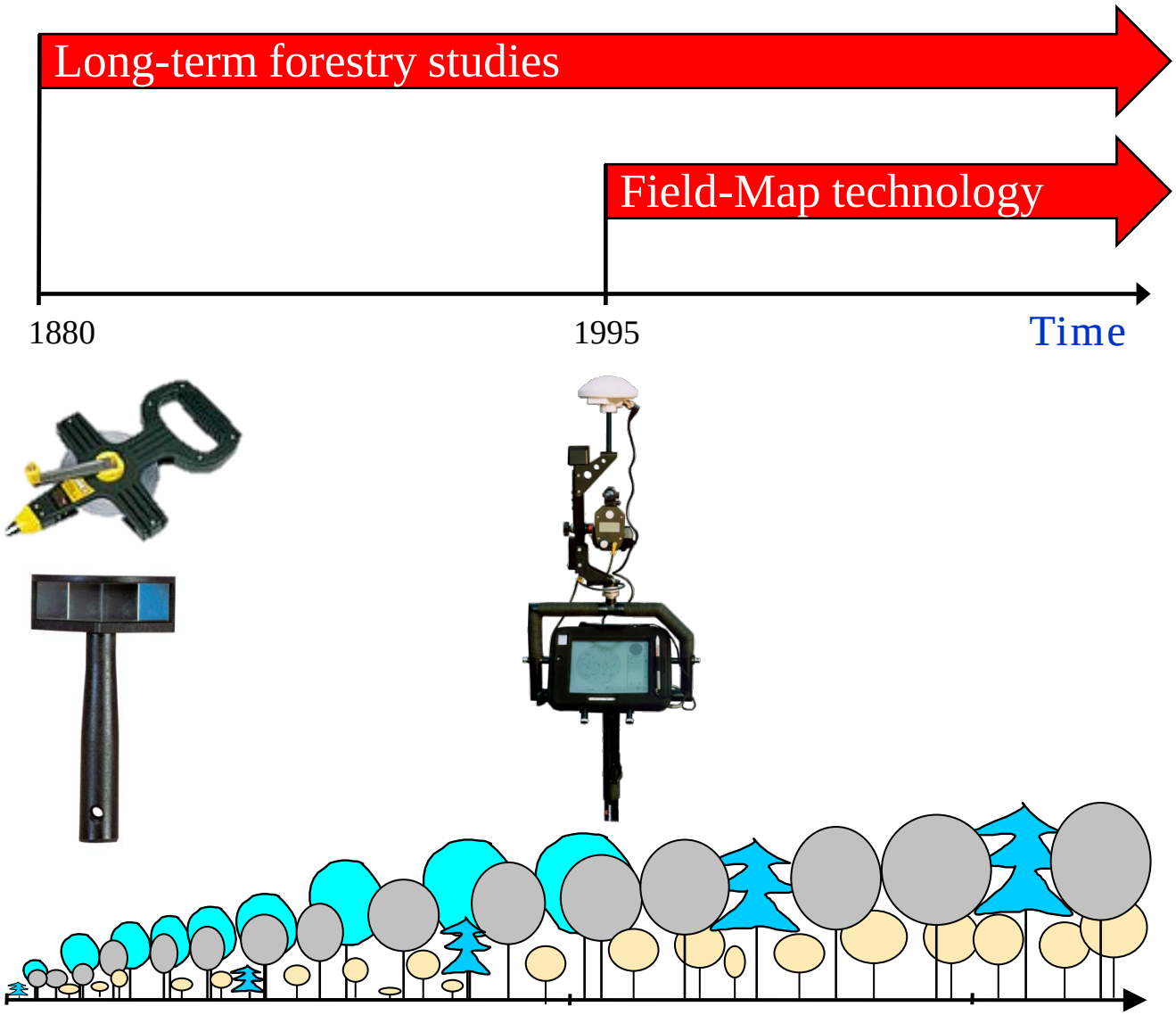
Content:

1. Introduction – what is the presentation about?
2. Spatial adjustment theory in a nutshell.
3. Selected example based on our experience.
4. Final remarks.

What is the presentation about?



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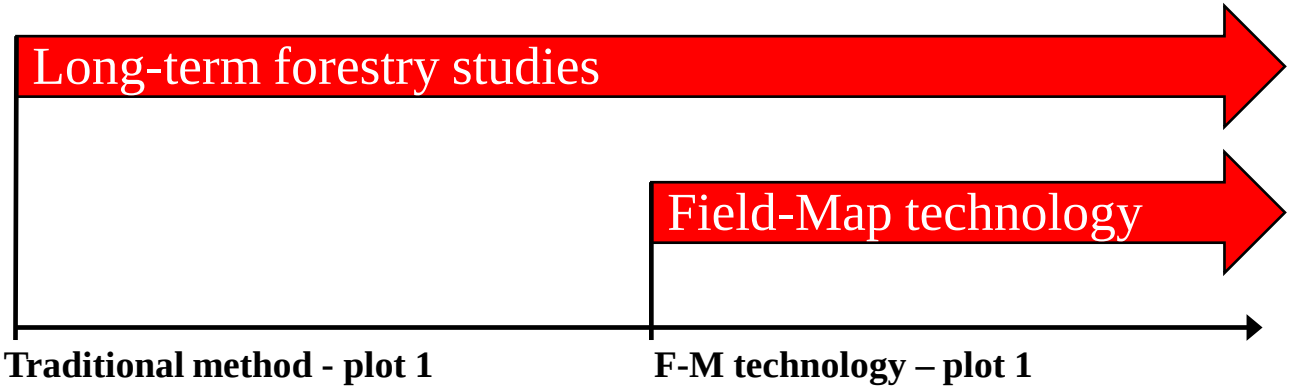

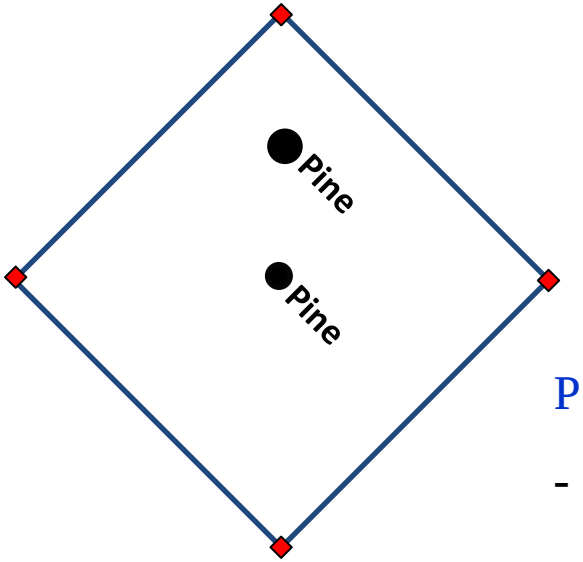

Pure Scots pine plot:

- 50 m x 50 m (0.25 ha),
- 4 poles at the corners,
- e.g. survey in 1994.

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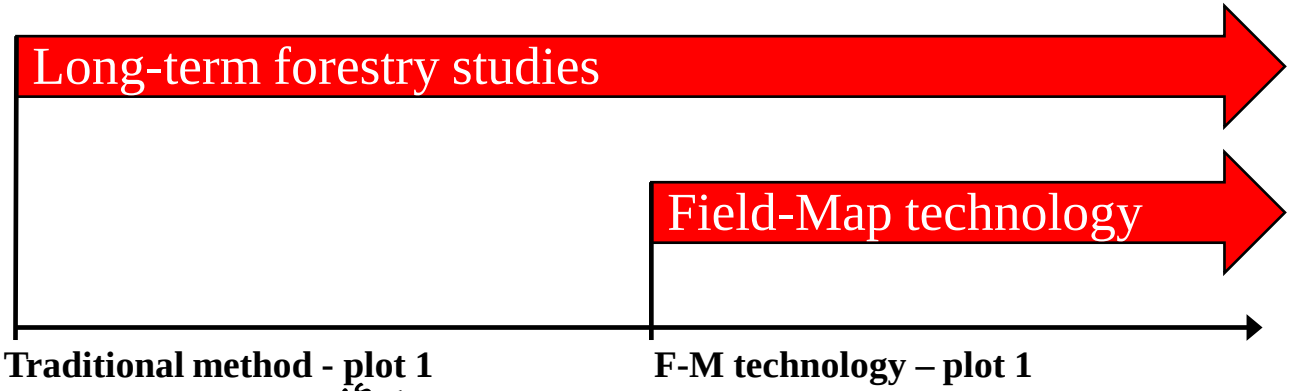

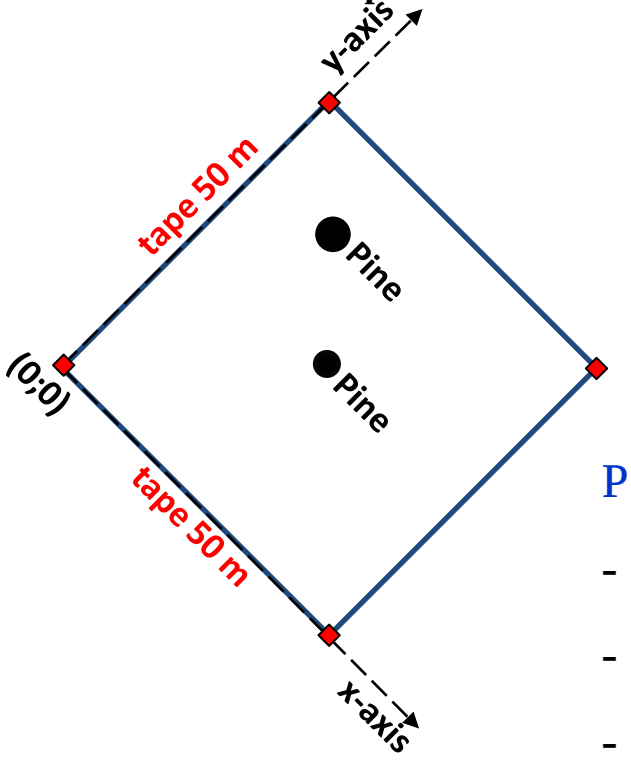

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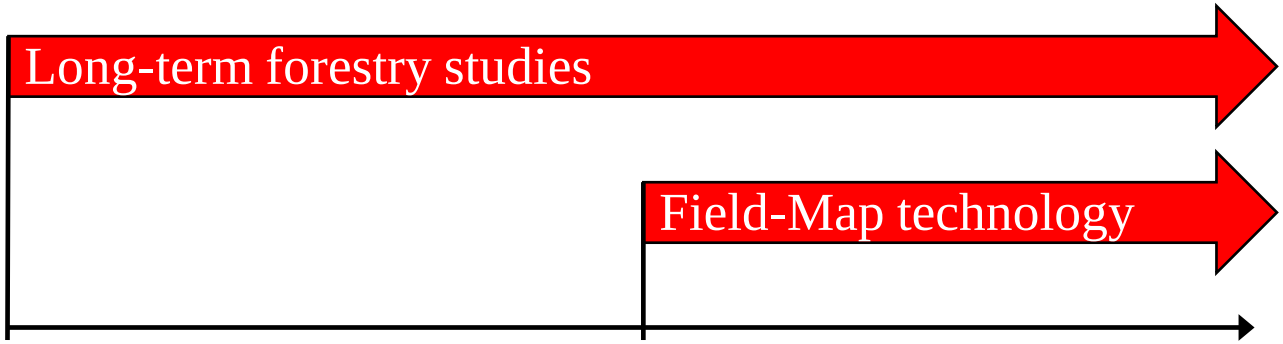

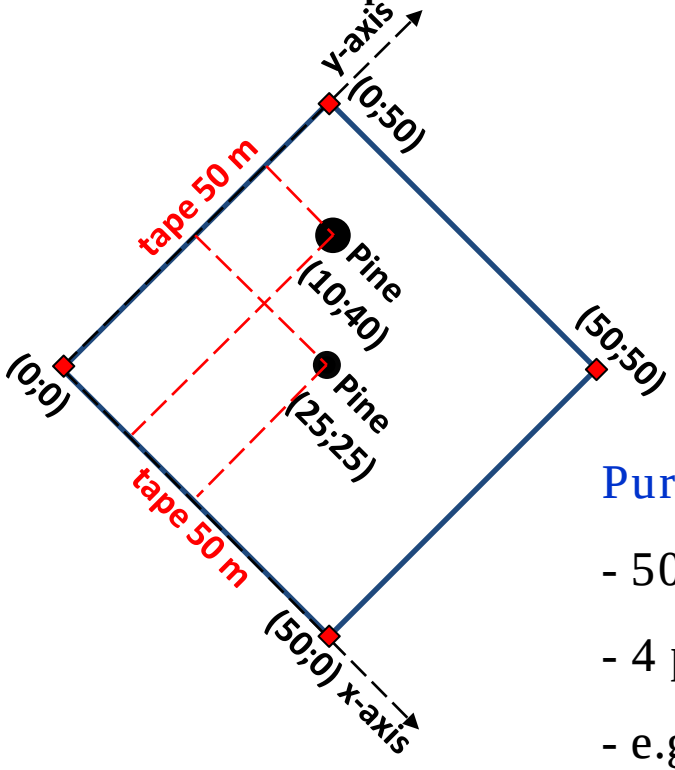

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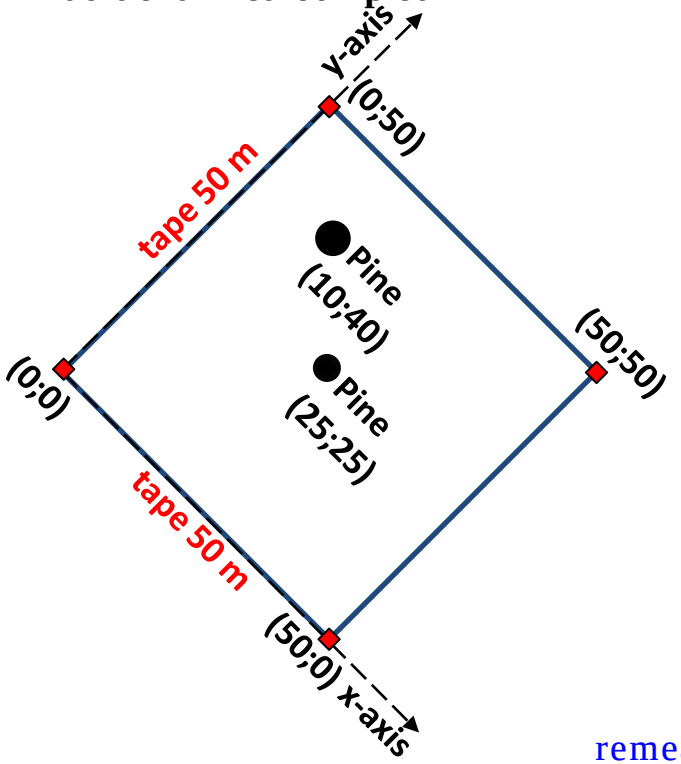
What is the presentation about?

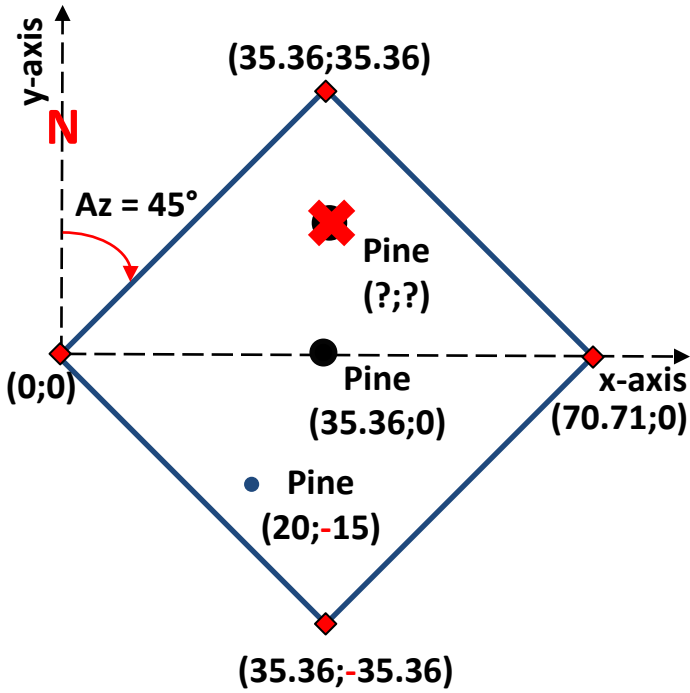
Long-term forestry studies

Field-Map technology

Traditional method - plot 1



F-M technology – plot 1



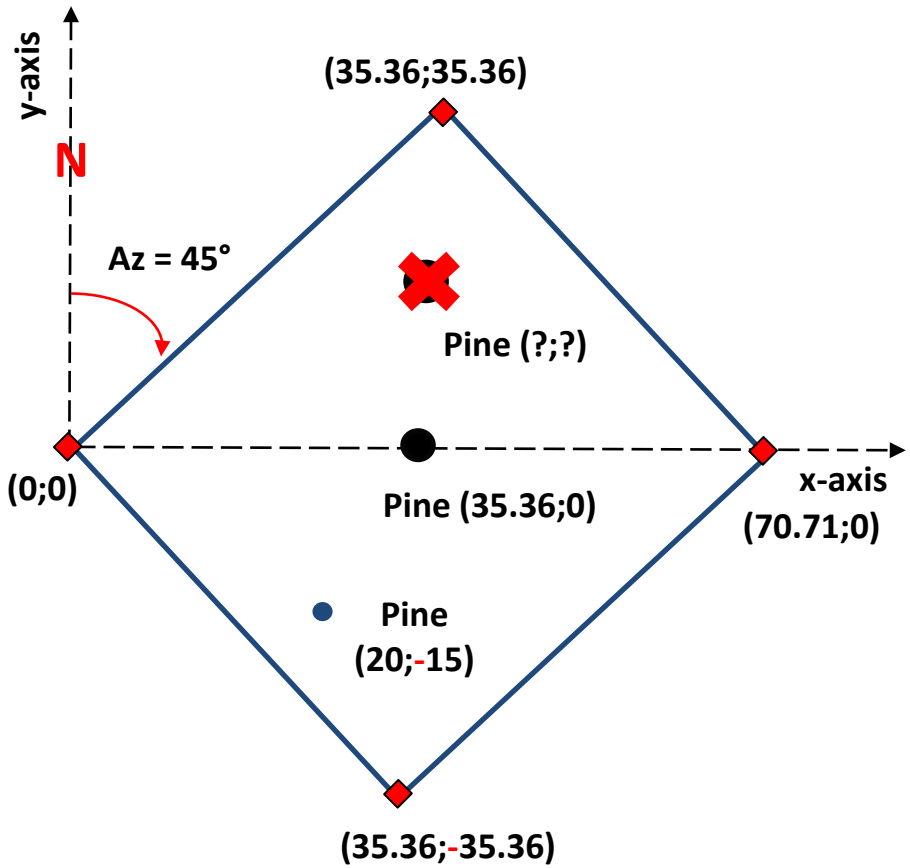
remeasured in 2014 – new coordinate system!

What is the presentation about?

Three categories of trees:

- survivors,
- dead trees,
- ingrowths.

F-M technology – plot 1



What is the presentation about?

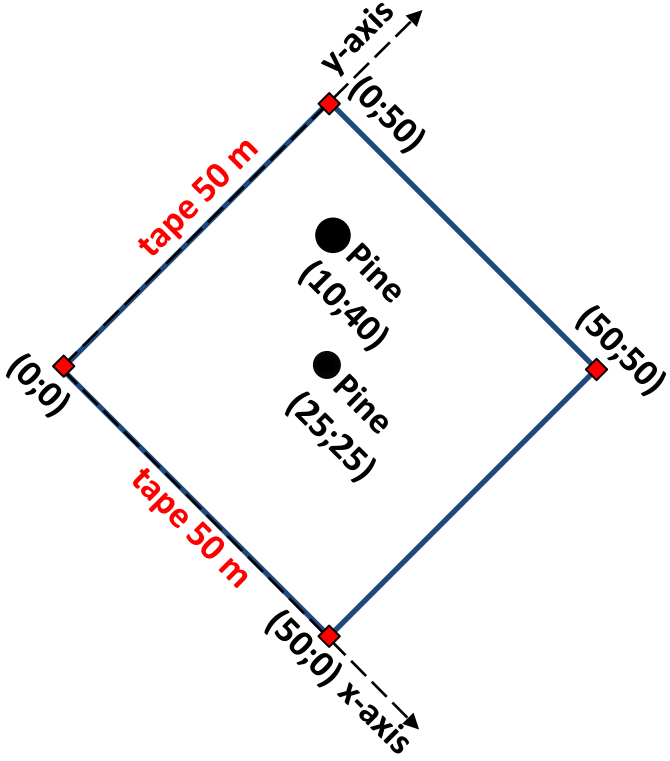
Database - 1994

Plot	Tree ID	Species	X	Y	DBH_94
1	1	Pine	10.00	40.00	50
1	2	Pine	25.00	25.00	30
...	...	...	...	...	...

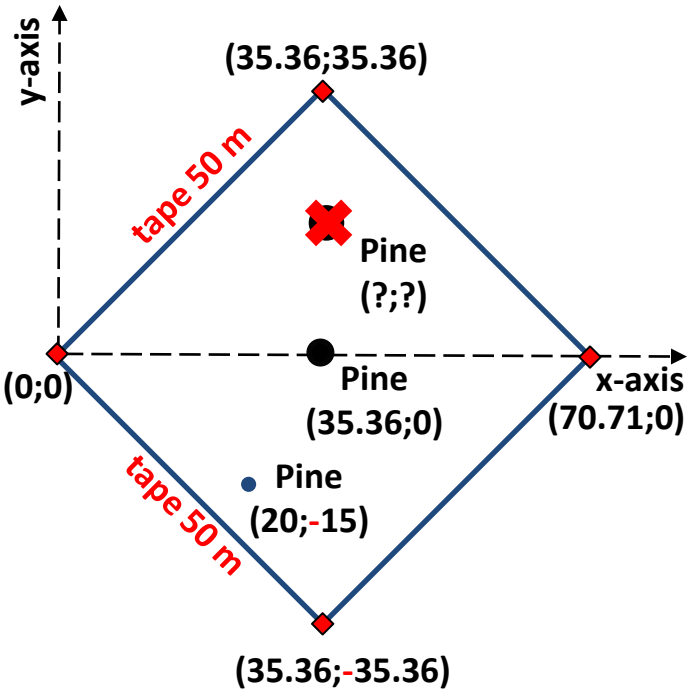
Database - 2014

Plot	Tree ID	Species	X	Y	X_fm	Y_fm	Z_fm	DBH_94	DBH_14
1	1	Pine	10.00	40.00	-	-	-	50	-
1	2	Pine	25.00	25.00	0.00	35.36	2.50	30	40
1	3	Pine	-	-	**20.00**	**-15.00**	1.00	-	20
...	...	...	...	...	...	...	...	...	...

Traditional method



F-M technology



What is the presentation about?

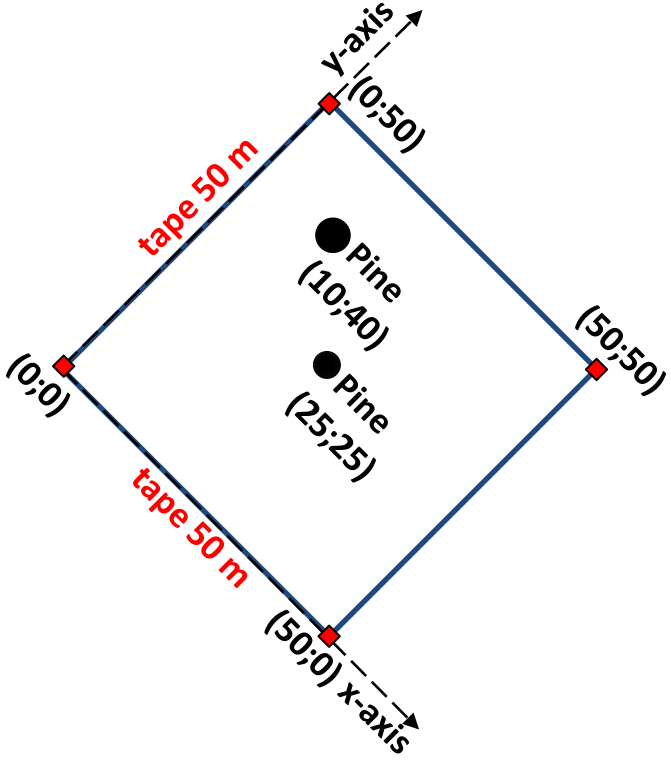
Database - 1994

Plot	Tree ID	Species	X	Y	DBH_94
1	1	Pine	10.00	40.00	50
1	2	Pine	25.00	25.00	30
...	...	...	...	...	...

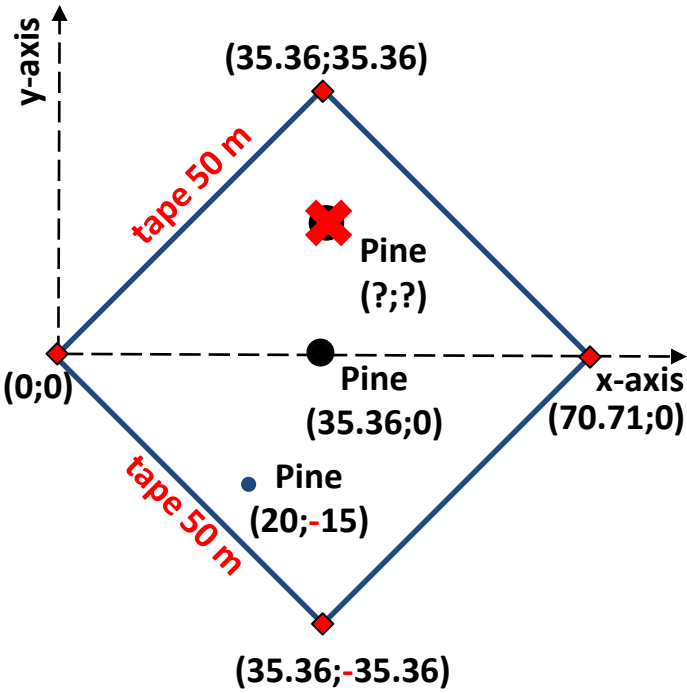
Database - 2014

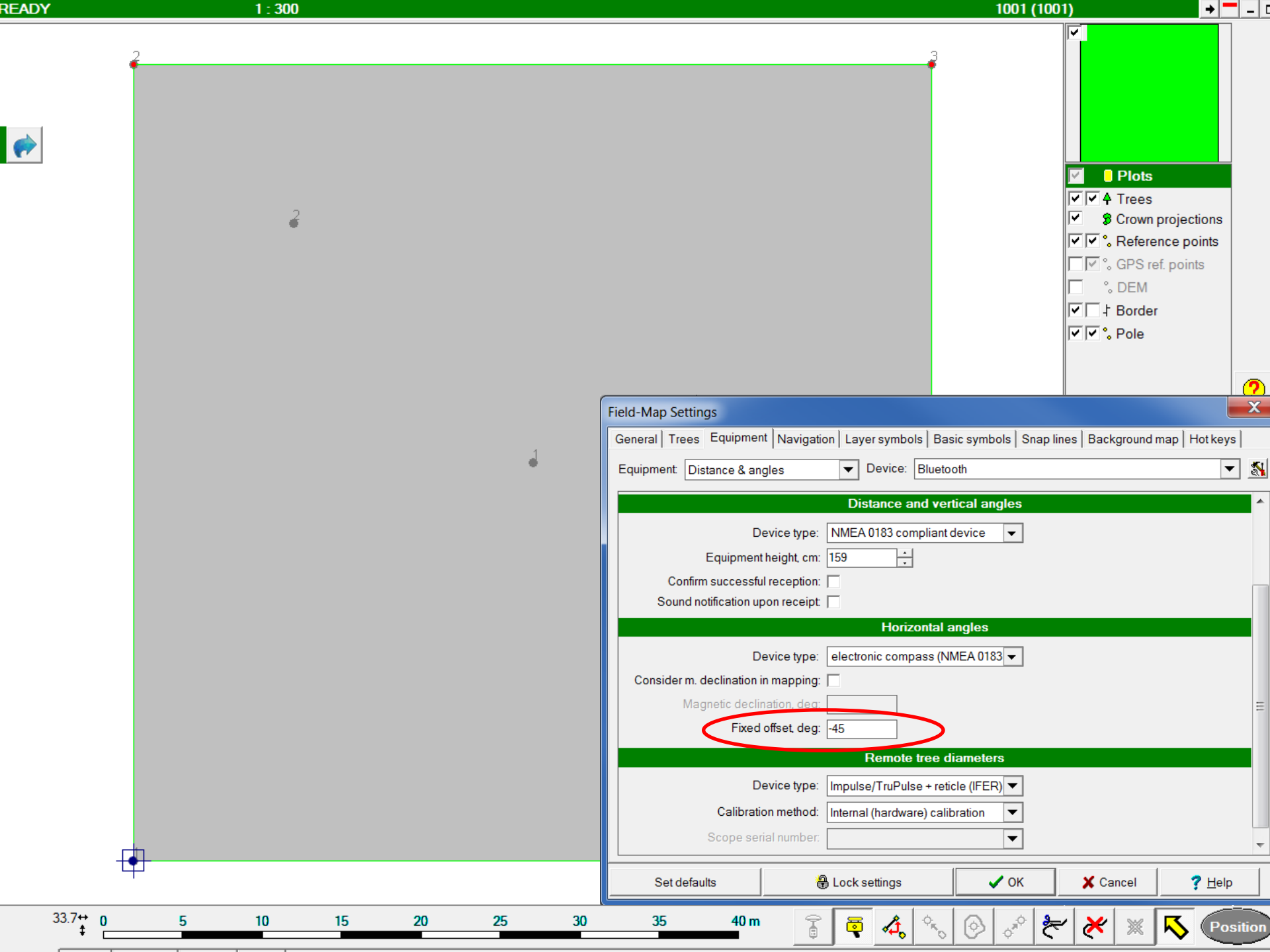
Plot	Tree ID	Species	X	Y	X_fm	Y_fm	Z_fm	DBH_94	DBH_14
1	1	Pine	10.00	40.00	?	?	?	50	-
1	2	Pine	25.00	25.00	0.00	35.36	2.50	30	40
1	3	Pine	?	?	20.00	-15.00	1.00	-	20
...	...	...	...	...	...	...	...	...	...

Traditional method



F-M technology




READY
1 : 300
1001 (1001)
Plots
Trees
Crown projections
Reference points
GPS ref. points
DEM
Border
Pole
Field-Map Settings
General
Trees
Equipment
Navigation
Layer symbols
Basic symbols
Snap lines
Background map
Hot keys
Equipment: Distance & angles
Device: Bluetooth
Distance and vertical angles
Device type: NMEA 0183 compliant device
Equipment height, cm: 159
Confirm successful reception:
Sound notification upon receipt:
Horizontal angles
Device type: electronic compass (NMEA 0183
Consider m. declination in mapping:
Magnetic declination, deg:
Fixed offset, deg: -45
Remote tree diameters
Device type: Impulse/TruPulse + reticle (IFER)
Calibration method: Internal (hardware) calibration
Scope serial number:
Set defaults
Lock settings
OK
Cancel
Help
33.7
0
5
10
15
20
25
30
35
40 m
Position

What is the presentation about?

Database - 1994

Plot	Tree ID	Species	X	Y	DBH_94
1	1	Pine	10.00	40.00	50
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...	...	...	...	...	...

Database - 2014

Plot	Tree ID	Species	X	Y	X_fm	Y_fm	Z_fm	DBH_94	DBH_14
1	1	Pine	10.00	40.00	?	?	?	50	-
1	2	Pine	25.00	25.00	0.00	35.36	2.50	30	40
1	3	Pine	?	?	20.00	-15.00	1.00	-	20
...	...	...	...	...	...	...	...	...	...

Traditional method → **F-M technology**

Summary 1:

We need to calculate:

1. Tree coordinates (X_fm and Y_FM) for tree no. 1, ie. tree that decayed;
2. Tree coordinate (X and Y) for tree no. 3, ie. new tree (ingrowth).

To this end we can use the following general formulas:

$$X' = X \cos Az - Y \sin Az$$

$$Y' = X \sin Az - Y \cos Az$$

e.g. for tree no. 3 and X_fm = 20 m and Y_fm = -15 m, X and Y respectively amount to 24.75 and 3.54 m

What is the presentation about?

Database - 1994

Plot	Tree ID	Species	X	Y	DBH_94
1	1	Pine	10.00	40.00	50
1	2	Pine	25.00	25.00	30
...	...	...	...	...	...

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1	2	Pine	25.00	25.00	0.00	35.36	2.50	30	40
1	3	Pine	?	?	20.00	-15.00	1.00	-	20
...	...	...	...	...	...	...	...	...	...

Traditional method

F-M technology

Summary 1 (cont.):

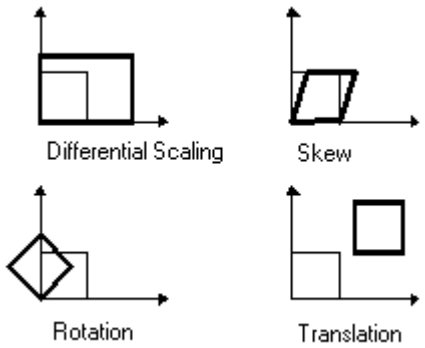
Different spatial adjustment mhetods available in ArcGIS software are a good option. They allow, in a simple way, to solve problems related to situations when plot is not orientated to the north direction, its shape varies greatly from a square or rectangular (plot sides are not at a right angle), and is located on terrain with a significant slope.

There are no such a problems problems in the case of permanent circular sample plots.

Spatial adjustment methods in a nutshell

1. Affine transformation

An affine transformation can differentially scale the data, skew it, rotate it, and translate it.



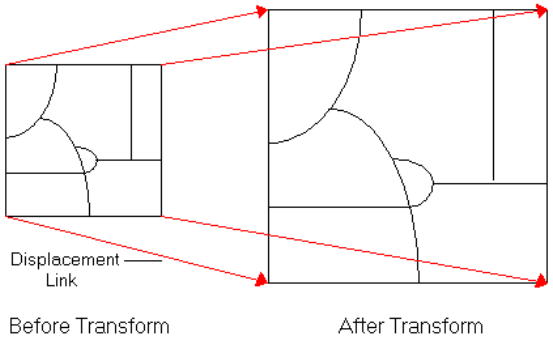
This method requires a minimum of three links. This is the recommended choice for most simple transformations.

Source: ArcGIS online resources

Spatial adjustment methods in a nutshell

2. Similarity transformation

The similarity transformation scales, rotates, and translates the data. It will not independently scale the axes, nor will it introduce any skew. It maintains the aspect ratio of the features transformed, which is important if you want to maintain the relative shape of features.



This method requires a minimum of two displacement links. However, three or more links are needed to produce a root mean square (RMS) error = error of transormation.

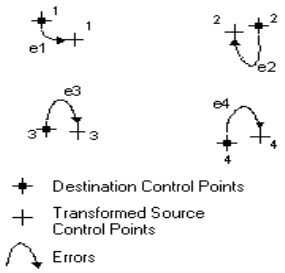
Source: ArcGIS online resources

Spatial adjustment methods in a nutshell

3. Projective transformation

The projective transformation is based on a more complex formula that requires a minimum of four displacement links. This method is used to transform data captured directly from aerial photography.

For each transformation a root mean square error is calculated. It indicates how good the derived transformation is, or in other words, it is a measure of the fit between the true locations and the transformed locations of the given points.



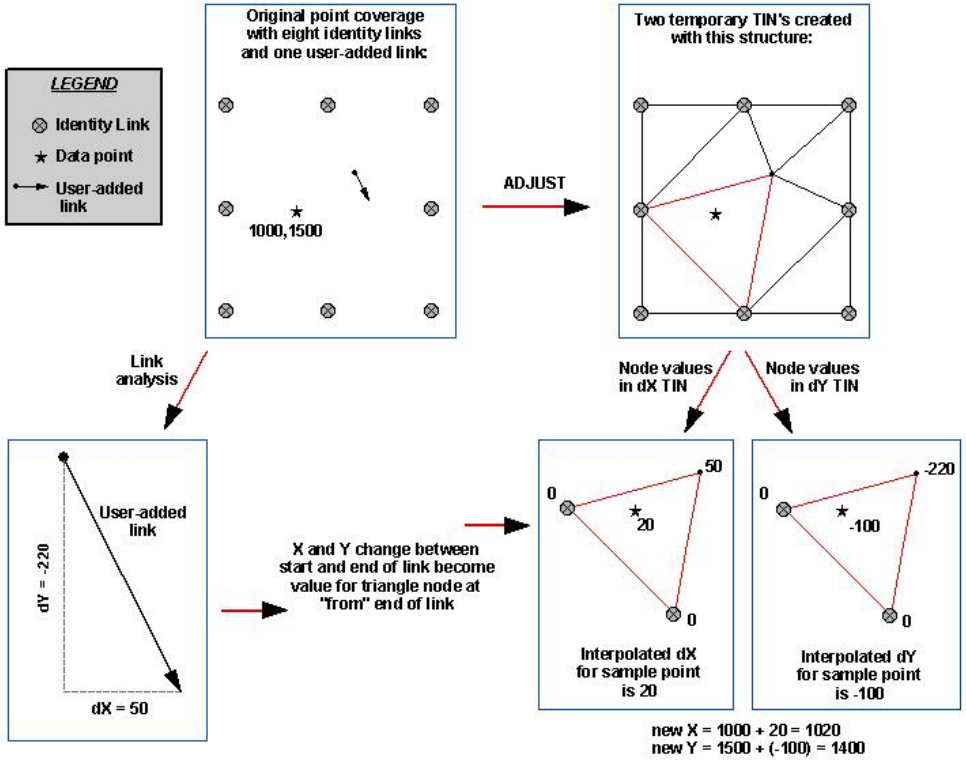
$$\text{RMS error} = \sqrt{\frac{e_1^2 + e_2^2 + e_3^2 + \cdots + e_n^2}{n}}$$

Source: ArcGIS online resources

Spatial adjustment methods in a nutshell

4. Rubbersheeting adjustment method

Rubbersheeting adjustment method corrects flaws through the expected and observed values.



Source: ArcGIS online resources

Spatial adjustment methods in a nutshell

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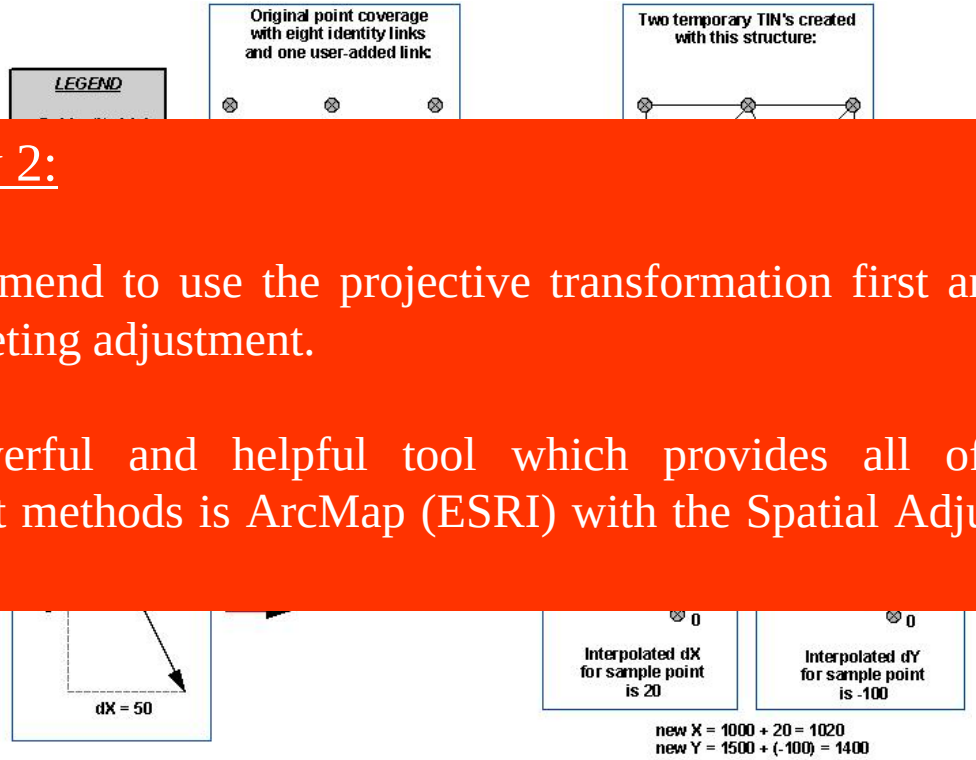


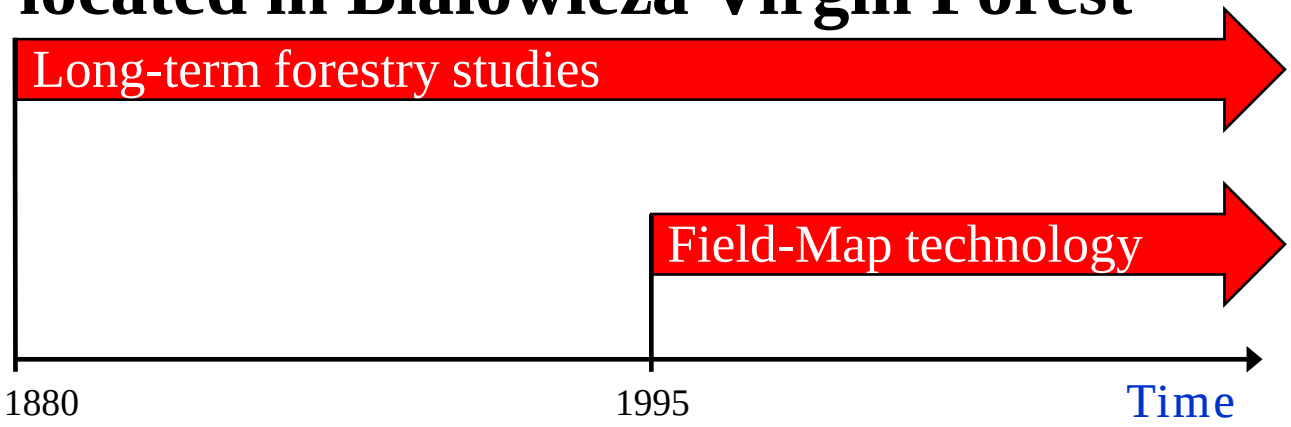
Source: ArcGIS online resources

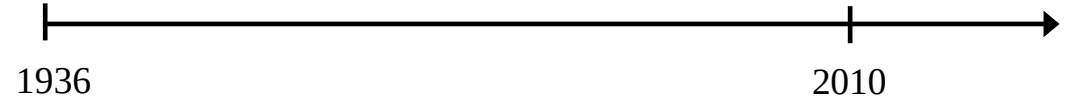
Summary 2:

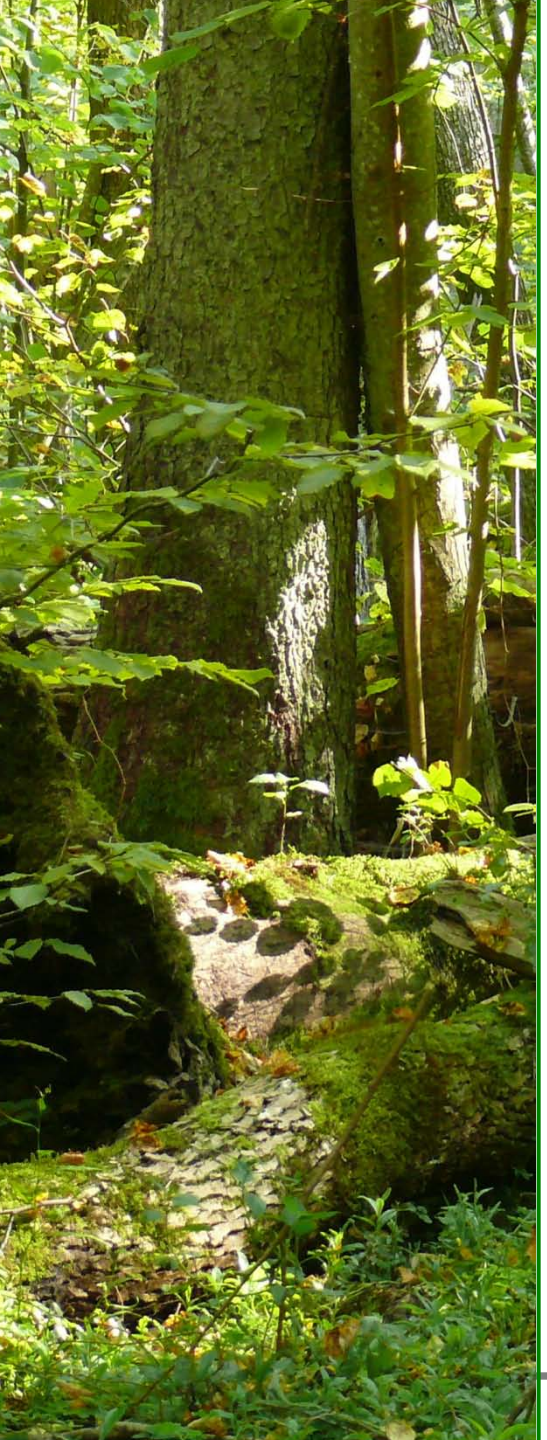
We recommend to use the projective transformation first and then rubbersheeting adjustment.

Very powerful and helpful tool which provides all of these adjustment methods is ArcMap (ESRI) with the Spatial Adjustment module.

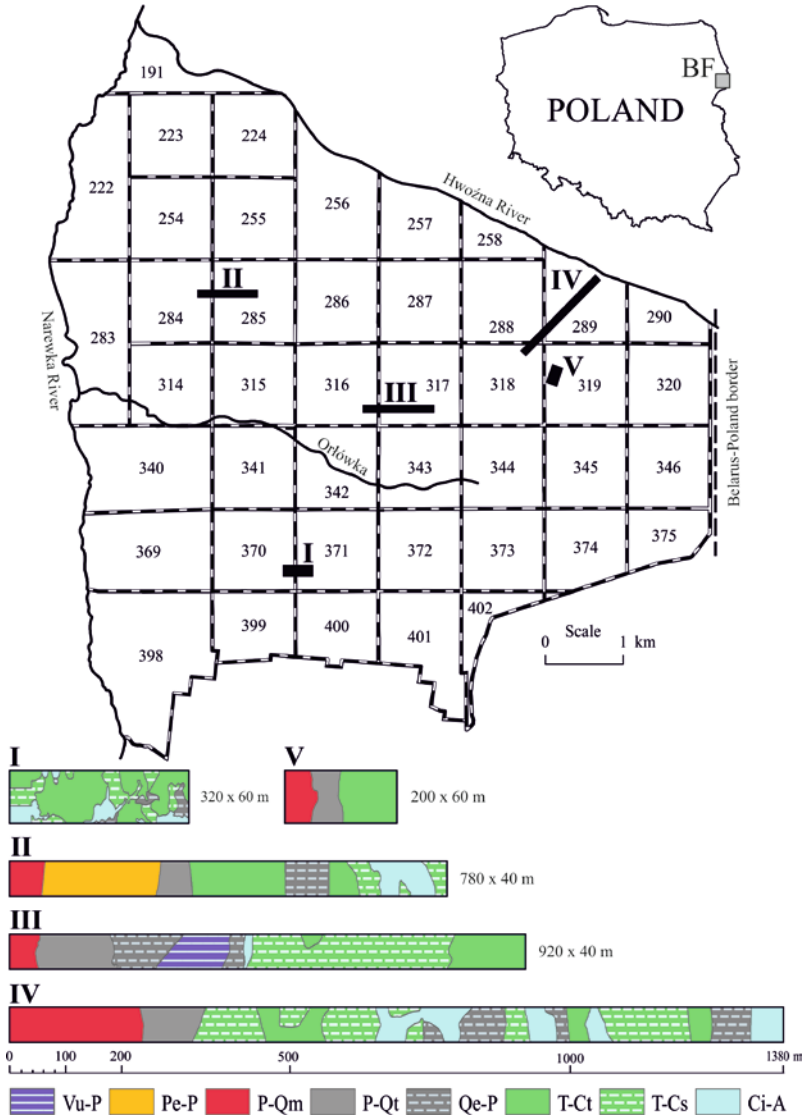
Our experience based on long-term plots located in Bialowieza Virgin Forest







Our experience based on long-term plots located in Bialowieza Virgin Forest



Since 1936

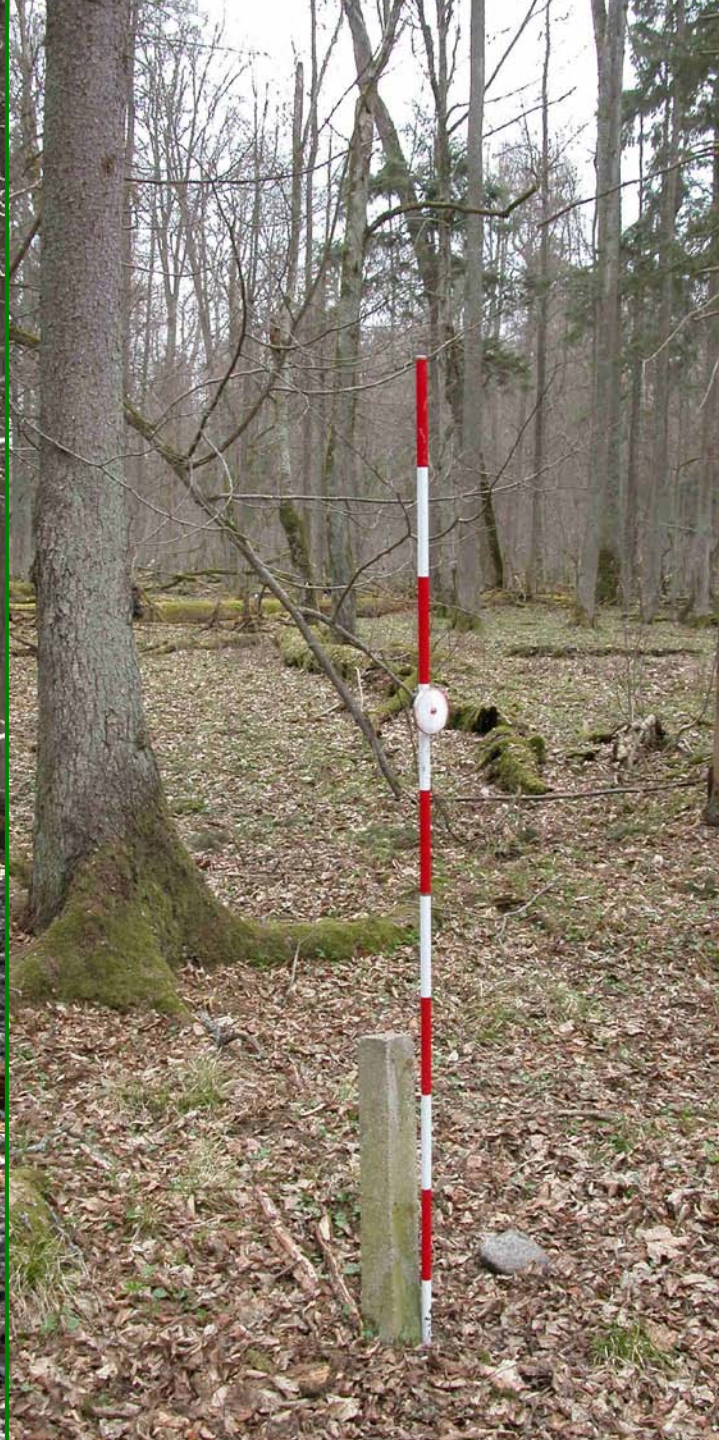
Spatio-temporal dynamics of natural forest

Reference for (close-to-nature) silviculture

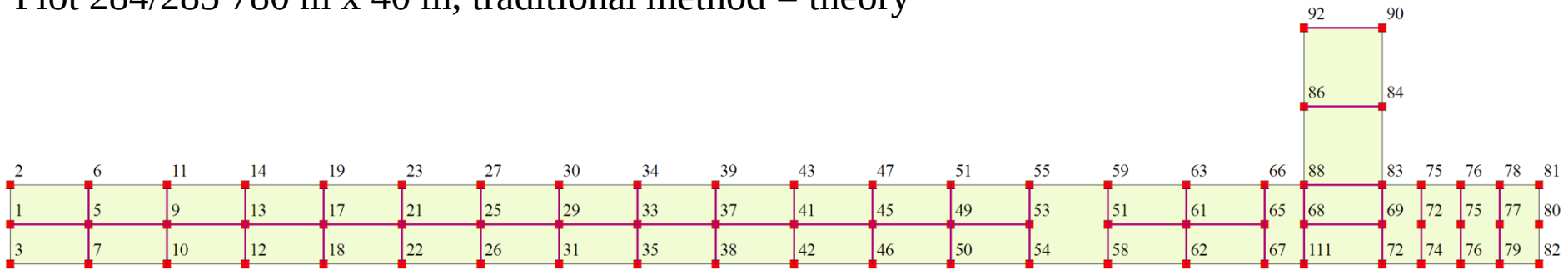
Our experience based on long-term plots located in Bialowieza Virgin Forest

Dates of records:

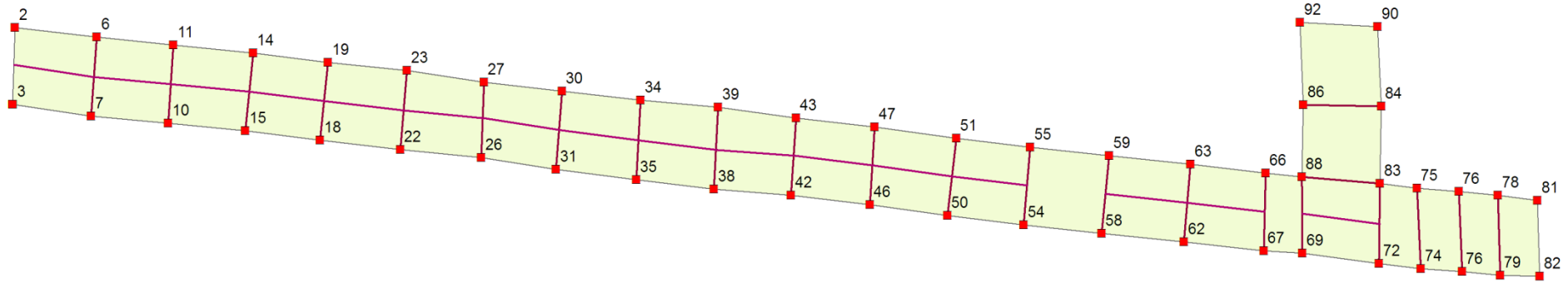
No	Comp.	Records						FM
		1	2	3	4	5	6	7
1	370/371	1936	1955	1971	1983	1993	2003	2013
2	284/285	1936	1959	1972	1982	1992	2002	2012
3	316/317	1936	1956	1971	1983	1993	2003	2013
4	318/288/ 289	1936	1956	1968	1981	1991	2001	2011
5	319	1936	1959	1969	1981	1991	2001	2011
Averaged year of records		**1936**	**1957**	**1970**	**1982**	**1992**	**2002**	**2012**

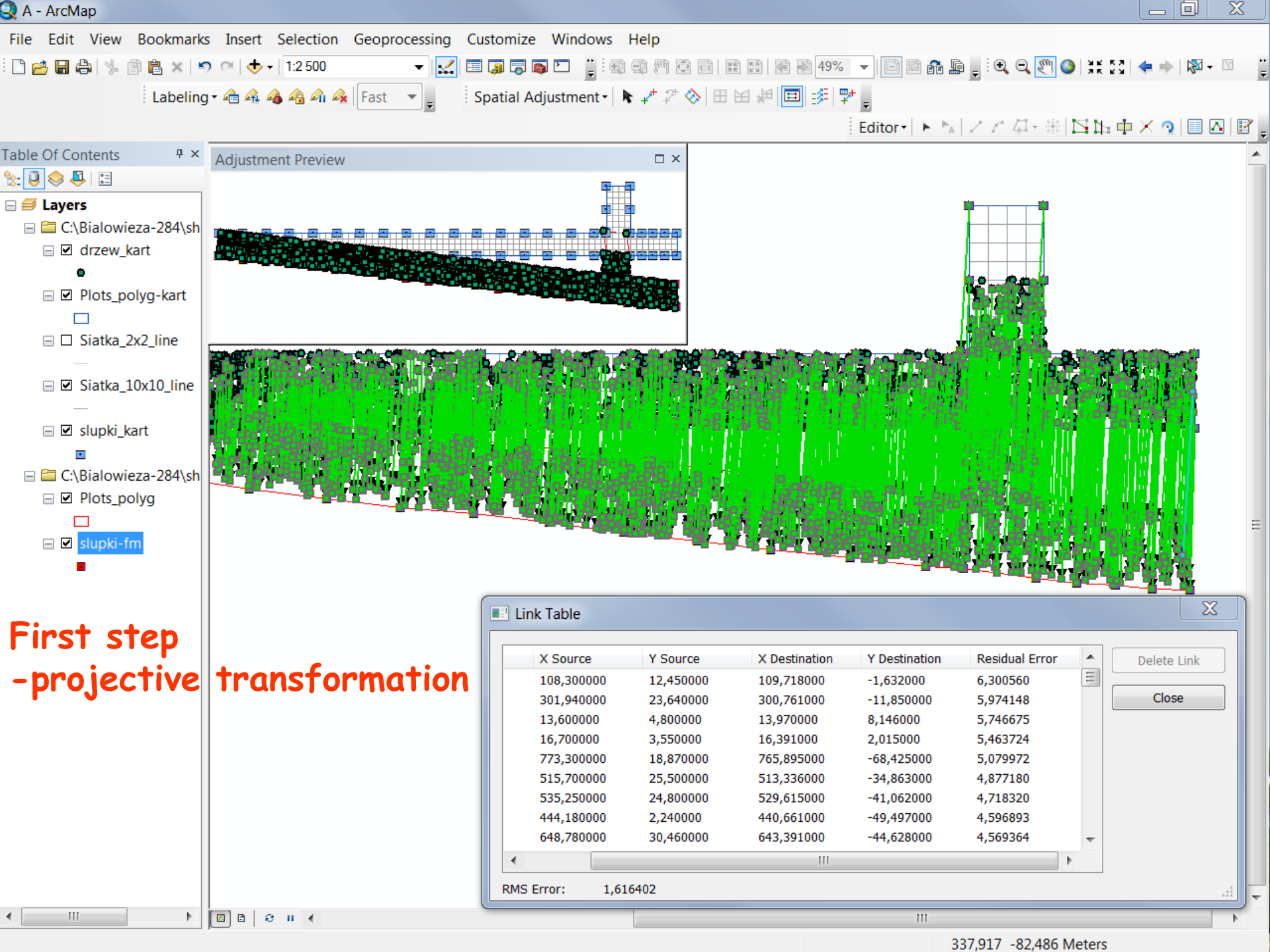


Plot 284/285 780 m x 40 m, traditional method = theory



Plot 284/285 780 m x40 m, F-M tchenology = reality

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Siatka_10x10_line
slupki_kart
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Adjustment Preview
Link Table
X Source Y Source X Destination Y Destination Residual Error
108,300000 12,450000 109,718000 -1,632000 6,300560
301,940000 23,640000 300,761000 -11,850000 5,974148
13,600000 4,800000 13,970000 8,146000 5,746675
16,700000 3,550000 16,391000 2,015000 5,463724
773,300000 18,870000 765,895000 -68,425000 5,079972
515,700000 25,500000 513,336000 -34,863000 4,877180
535,250000 24,800000 529,615000 -41,062000 4,718320
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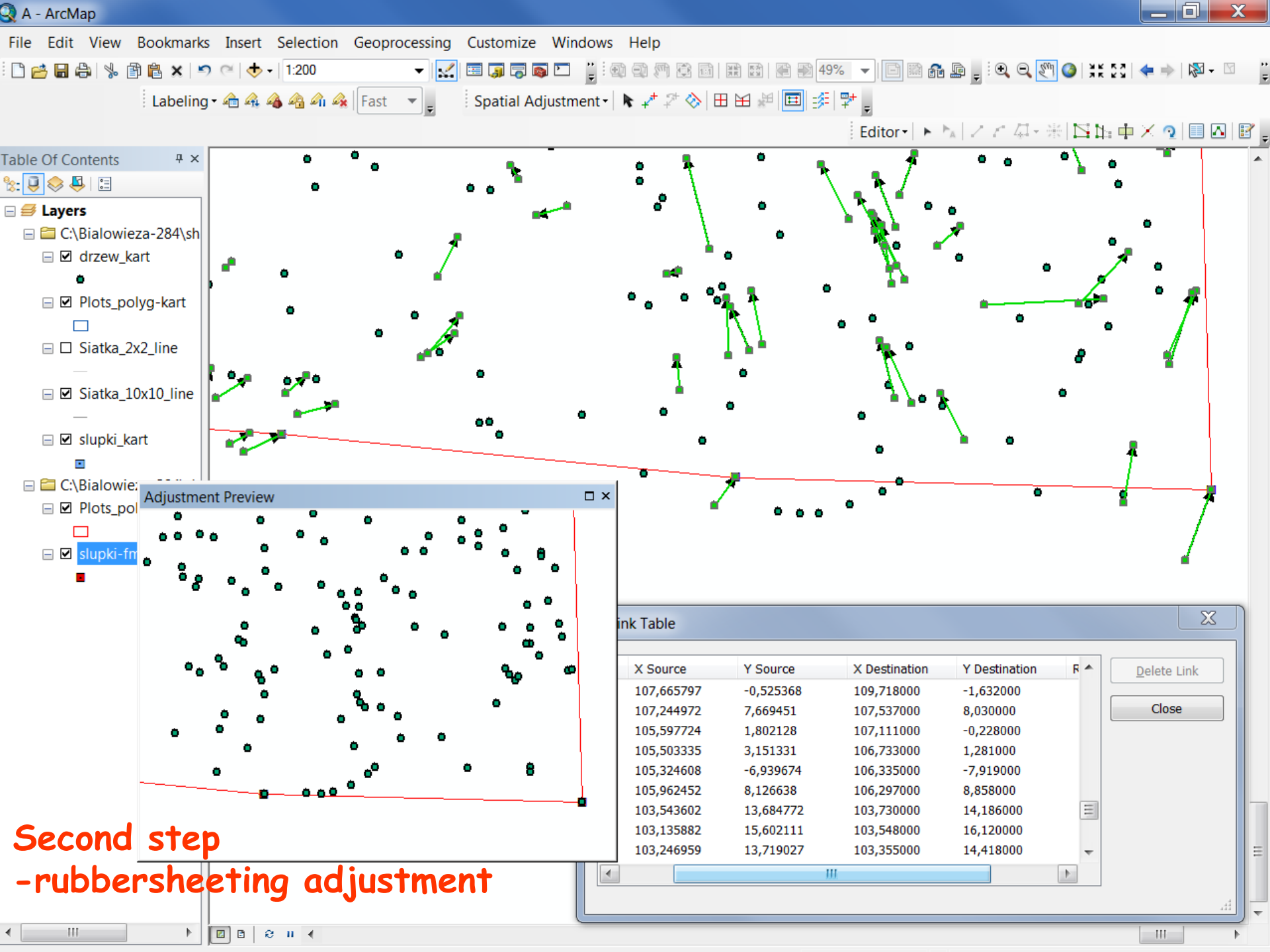
RMS Error: 1,616402
First step
-projective transformation
337,917 -82,486 Meters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Spatial Adjustment
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Siatka_10x10_line
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107,665797 -0,525368 109,718000 -1,632000
107,244972 7,669451 107,537000 8,030000
105,597724 1,802128 107,111000 -0,228000
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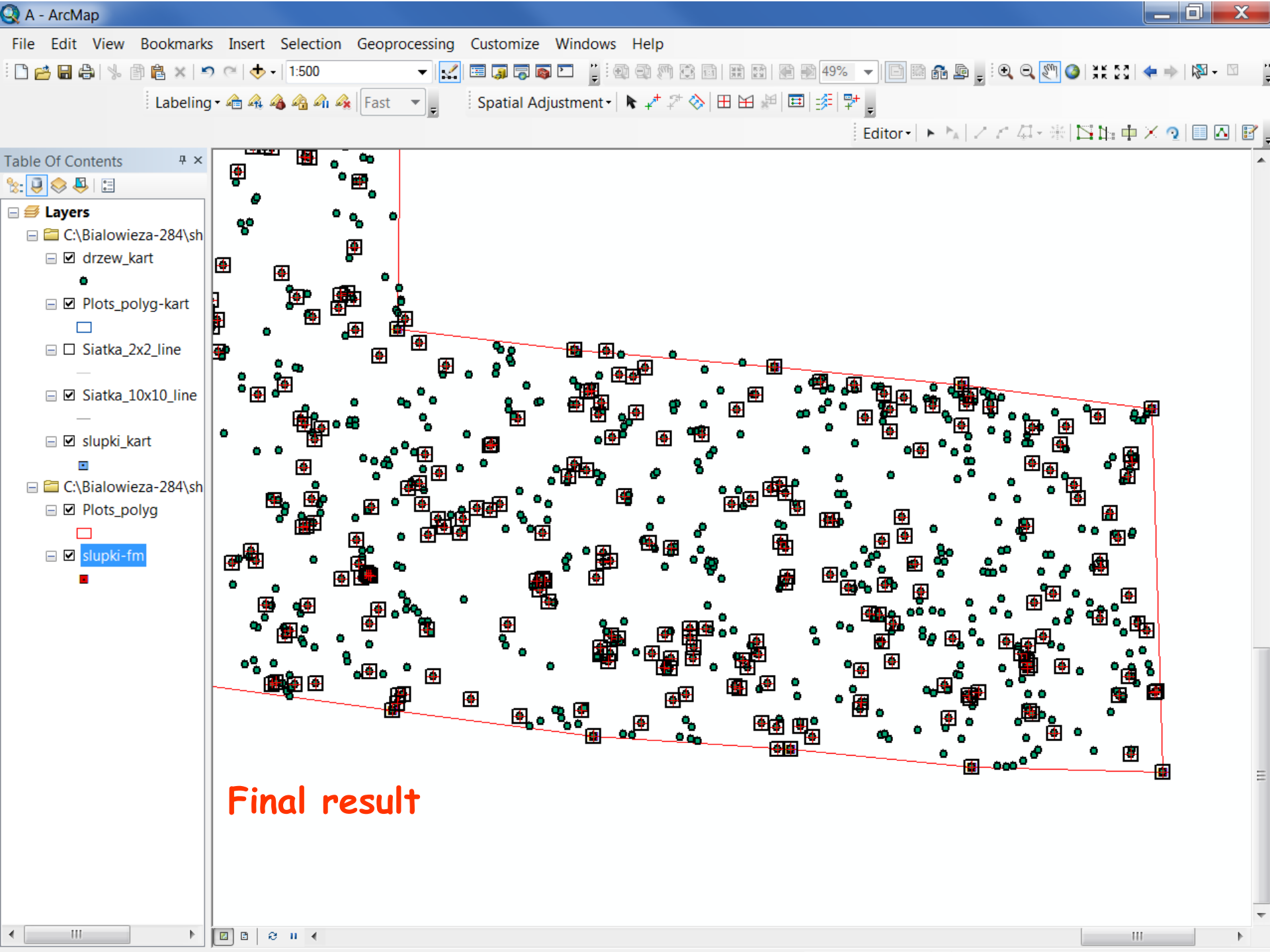
105,962452 8,126638 106,297000 8,858000
103,543602 13,684772 103,730000 14,186000
103,135882 15,602111 103,548000 16,120000
103,246959 13,719027 103,355000 14,418000
Delete Link
Close
Second step
-rubbersheeting adjustment


A - ArcMap
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Editor
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Siatka_2x2_line
Siatka_10x10_line
slupki_kart
C:\Bialowieza-284\sh
Plots_polyg
slupki-fm
Final result

B - ArcMap

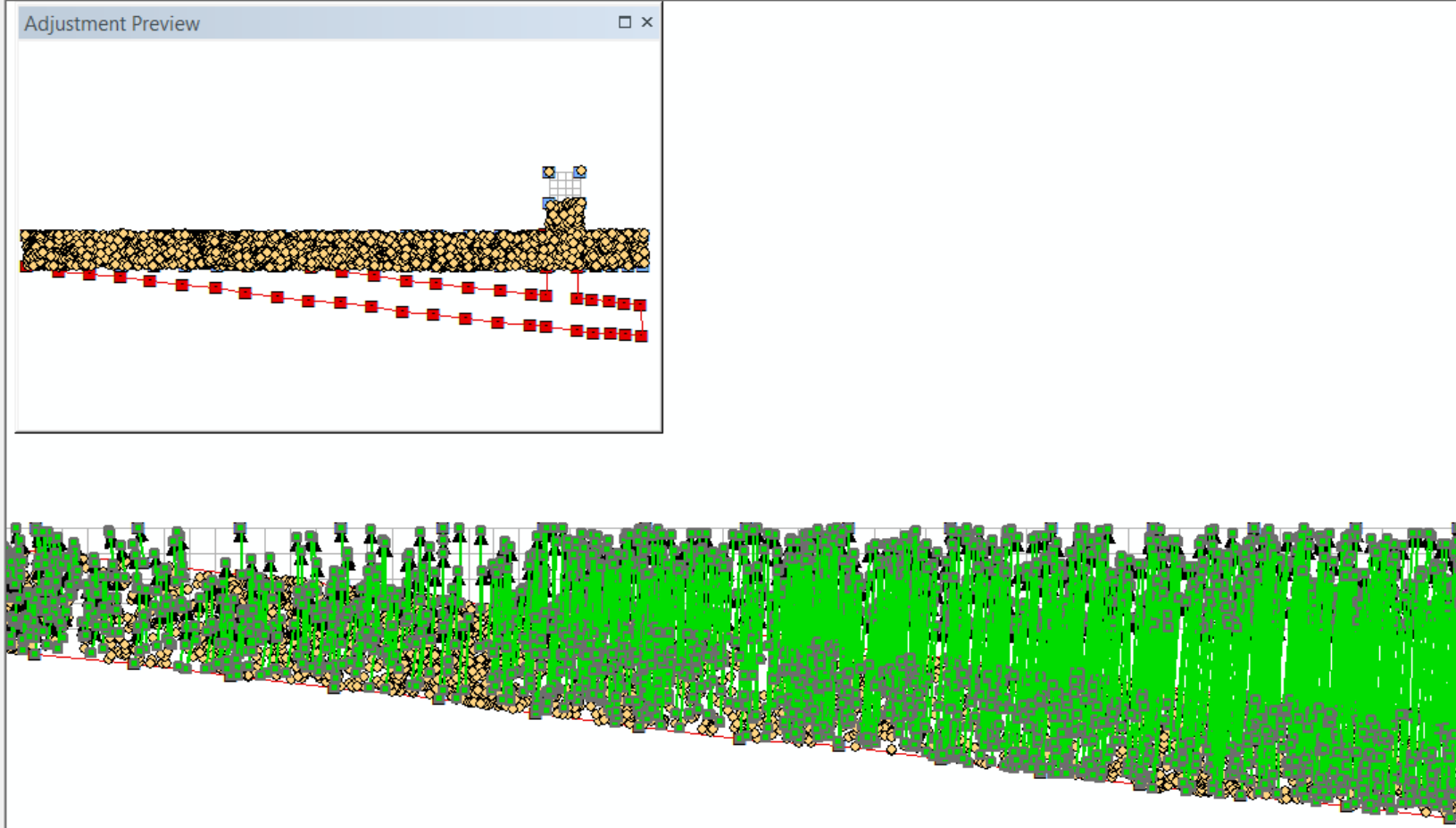
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help

1:2 500 | 100% | Labeling | Fast | Spatial Adjustment | Editor

Table Of Contents

- Layers
  - drzew_fm
  - Plots_polyg
  - slupki-fm
  - slupki_kart
  - Siatka_10x10_line
  - Plots_polyg-kart

Adjustment Preview



Transformation from F-M coordinate spatial system to traditional one.

Link Table

ID	X Source	Y Source	X Destination	Y Destination
1502	109,718000	-1,632000	108,300000	12,450000
1182	300,761000	-11,850000	301,940000	23,640000
1730	13,970000	8,146000	13,600000	4,800000
1731	16,391000	2,015000	16,700000	3,550000
36	765,895000	-68,425000	773,300000	18,870000

Conclusions:

1. From our practice the efficiency of survey of spatial coordinates by means of Field-Map technology fluctuates between 1.5 and 2 in comparison to the traditional methods.

2. The new (FM-collected) coordinates are more precise, however the old ones are necessary in order to reconstruct positions of currently absent (dead) trees.

3. The ESRI ArcMap software can be an efficient tool for adjustment of spatial coordinate systems originated from different measurements technologies.