Validation of methods for measurement of land parcel areas

Beata Hejmanowska

Validation of methods for measurement of land parcel areas

- State of art:
  - Control procedure in IACS concerns measurements of land parcel area
  - Measured and declared parcel areas are compared according so called technical tolerance of measurement (max. 5% of relative area error)
  - Technical tolerance is defined by width of the buffer around the parcel border (1.5 m for ortophotomap in scale of 1:10000, 1.25m for GPS, 0.35 for total station)
  - Technical tolerance should reflect measurements accuracy and therefore validation measurements are needed
  - Surveying formulas couldn’t be adapted
- Aim of the project was elaboration of validation methods for measurement of land parcels areas *(main and supplementary study)*

Validation of methods for measurement of land parcel areas

Background:
- *elaboration validation method appying ISO norm*
- *performing measurement experiment*
- *propose ev. alternative to buffer accuracy parameter*

Coordination institution :

• AGH-University of Science and Technology, Kraków Poland **(AGH UST Kraków)** **Remote Sensing**

– **Dr Eng. Beata Hejmanowska**

Subcontractors:

•University of Warmia and Mazury in Olsztyn, Olsztyn, Poland **(UWM Olsztyn)** **GPS**

–**Prof. Dr hab. Eng. Stanisław Oszczak**

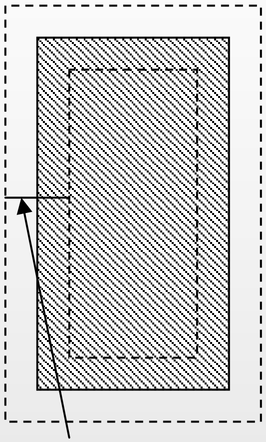
–**Dr Eng. Adam Ciećko**

•Unite de Statistique et Informatique, Faculte universitaire des Sciences agronomiques, Gembloux, Belgique **(USI Gembloux)** **Statistics**

–**Prof. Rudy Palm**

Existing approaches JRC

Area measurement tolerance for maps and ortophotomaps



Tolerance

Map scale	Pixel size [m]	Tolerance [%]	Tolerance [m]
1: 10 000	1	5	1.5
1: 5 000	0.5	2.5	0.75
1: 2 500	0.25	1.25	0.4

Area measurement tolerance for direct measurements

Map scale	Tolerance [%]	Tolerance [m]
GPS standalone	-	1.25
Geodetic surveying	2	0.35
Wheel, tape	2 (up to 50m) or 5	0.4

1. *What buffer value should be assumed?*
2. *If not buffer that what?*

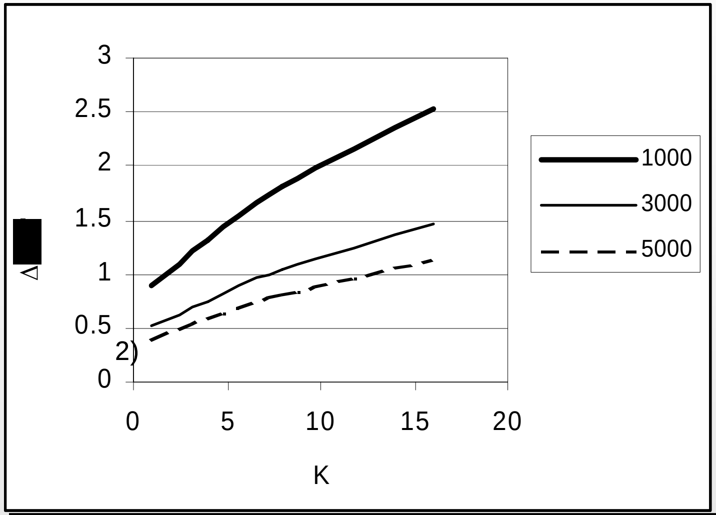
Existing approaches cadastre Poland

1) 2003 $\Delta P = 0.001 \cdot P + 0.2 \cdot \sqrt{P})$

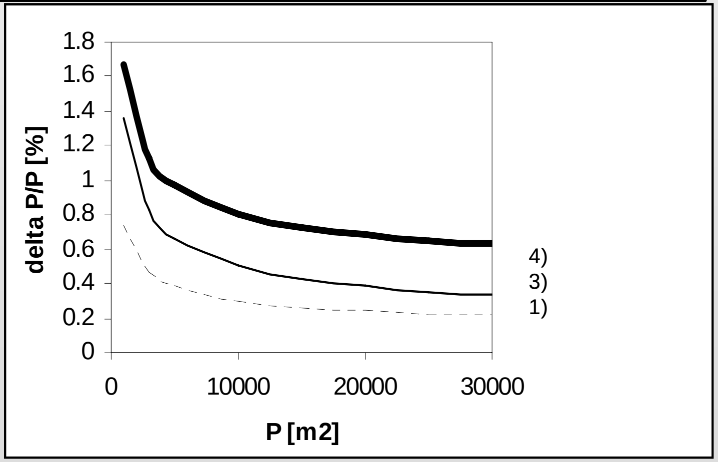
2) 1992 $\Delta P = 0.4 \cdot \sqrt{2P} \cdot \sqrt{\frac{1+K^2}{2K}}$

3) 1992 $\Delta P = 0.001 \cdot P + 0.0002 \cdot M \cdot \sqrt{P})$

4) 1998 $\Delta P = 2 \cdot (0.002 \cdot P + 0.2 \cdot \sqrt{P})$



ΔP – allowed discrepancies between area in cadastre and area measured during control measurement [m^2],
P – land parcel area [m^2]

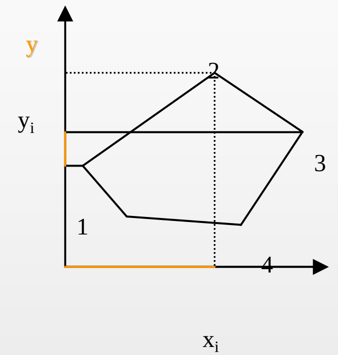


- *empirical formulas*
- *accuracy much below IACS limit 5%*

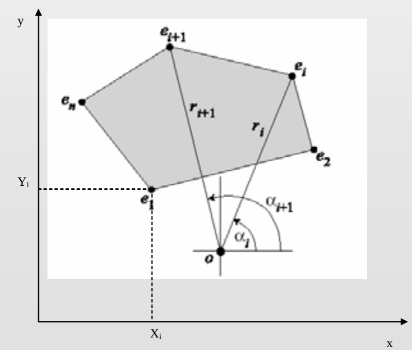
Area accuracy - point position error

- Coefficient calculations for accuracy estimations
  - (Hejmanowska B. 2003, Bogaert P., Delince J., Kay S. 2005):

$$m_P = m_{pkt}\sqrt{\sum_{i=1}^{n}\frac{(y_{i+1}-y_{i-1})^2+(x_{i-1}-x_{i+1})^2}{8}}$$



$$m_P = m_{pkt}\sqrt{\frac{1}{2}\sum_{i=1}^{n}(r_i^2 - r_i r_{i+2}\cos(\alpha_{i+2}-\alpha_i))}$$



where:
m_P – area error,
m_{pkt} – point position error
x, y – Cartesian coordinate of parcel vertices
r, a - polar coordinate of parcel vertices.
n – number of parcels vertices.

m_P= m_{pkt} Area_error_cofficient

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Area error calculation

1

7415098.04	5557121.93
7415122.02	5557120.95
7415132.21	5557002.98
7415103.29	5556997.39
7415098.04	5557121.93

→ m_p=2.8%

m_{pkt}=1m

HB

$$m_p = m_{pkt}\sqrt{\sum_{i=1}^{n}\frac{(y_{i+1}-y_{i-1})^2+(x_{i-1}-x_{i+1})^2}{8}}$$

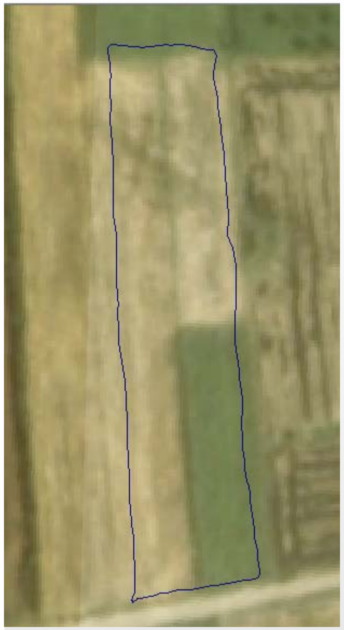
$$m_P = m_{pkt}\sqrt{\frac{1}{2}\sum_{i=1}^{n}(r_i^2 - r_i r_{i+2}\cos(\alpha_{i+2}-\alpha_i))}$$

BDK

$m_p=m_{pkt}$* AEC $m_{pkt}=m_p$/AEC

1

7415103.6576	5556996.5879
7415103.6605	5556996.7736
7415103.6605	5556996.7736
7415103.6635	5556996.9594
7415103.5405	5556996.9613
7415103.6635	5556996.9594
7415103.6635	5556996.9594
7415103.5405	5556996.9613
7415103.4256	5556997.1489
7415103.6753	5556997.7001
7415104.0475	5556998.8078
7415104.0711	5557000.2892
7415104.0947	5557001.7729
7415103.9967	5557003.0716
7415104.0173	5557004.3695
7415104.0380	5557005.6674
7415103.9407	5557006.9661
7415103.8464	5557008.4516
7415103.8700	5557009.9342
7415103.7707	5557011.4198
7415103.6734	5557012.7196
7415103.4604	5557014.2059
7415103.3631	5557015.5057
7415103.1458	5557016.9921
7415103.0486	5557018.2919
7415102.9506	5557019.5917
7415102.9712	5557020.8885
7415102.8697	5557022.1884
7415102.8903	5557023.4863
7415102.7952	5557024.9697
7415102.8159	5557026.2665
7415102.7186	5557027.5663
7415102.6213	5557028.8661
7415102.5233	5557030.1648
7415102.4247	5557031.6504
7415102.4483	5557033.1329
7415102.3533	5557034.6185
7415102.3769	5557036.1022
7415102.2826	5557037.5866
7415102.3062	5557039.0702
7415102.2118	5557040.5536
7415102.1175	5557042.0380
7415102.0182	5557043.5236
7415101.9238	5557045.0080
7415101.8288	5557046.4936
7415101.6115	5557047.9800
7415101.5172	5557049.4655
7415101.1863	5557050.9526
7415100.8481	5557052.2562
7415100.6352	5557053.7425
7415100.5336	5557055.0424
7415100.4385	5557056.5268



↓ m_p=0.4%

New approach in cadastre

- Correlation between parcels
  - „A Variance and Covariance Equation for Area Estimates with a Geographic Information System" P. A. J. van Oort, A. Stein, A. K. Bregt, S. de Bruin, and J. Kuipers

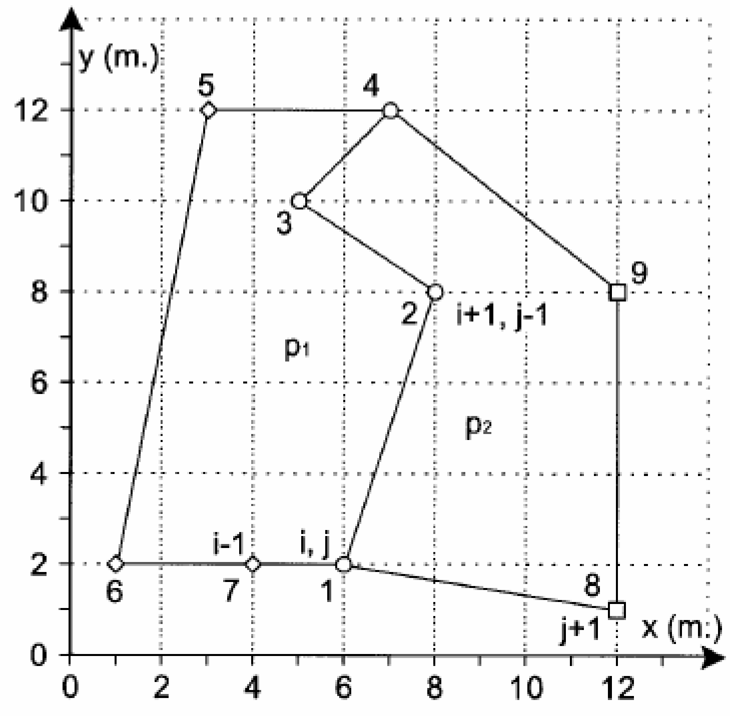


Figure 2. Two polygons with reference to vertex numbers.

$$\begin{aligned}
&\operatorname{cov}(A(p_q), A(p_r)) \\
&= \frac{1}{8} \cdot \sum_{i=1}^{n_q} \sum_{j=1}^{n_r} \delta(s_q(i), s_r(j)) \\
&\cdot \begin{bmatrix} \sigma_x^2(i) \cdot (y_q(i+1) - y_q(i-1)) \cdot (y_r(j+1) - y_r(j-1)) \\ + \sigma_y^2(i) \cdot (x_q(i+1) - x_q(i-1)) \cdot (x_r(j+1) - x_r(j-1)) \end{bmatrix} \\
&- \frac{1}{8} \cdot \sum_{i=1}^{n_q} \sum_{j=1}^{n_r} \delta(s_q(i), s_r(j)) \cdot \sigma_x^2(i) \\
&\cdot \begin{bmatrix} \delta(s_q(i+1), s_r(j-1)) \cdot \sigma_y^2(i+1) \\ + \delta(s_q(i-1), s_r(j+1)) \cdot \sigma_y^2(i-1) \end{bmatrix}.
\end{aligned} \qquad (12)$$

$$\begin{aligned}
\operatorname{var}(A(p_q)) = \frac{1}{4} \cdot \sum_{i=1}^{n_q} &[\sigma_x^2(i) \cdot (y_q(i+1) - y_q(i-1)^2 \\
&+ \sigma_y^2(i) \cdot (x_q(i+1) - x_q(i-1))^2] \qquad (9) \\
&+ \frac{1}{4} \cdot \sum_{i=1}^{n_q} [\sigma_x^2(i) \cdot (\sigma_y^2(i+1) + \sigma_y^2(i-1))].
\end{aligned}$$

Plan of measurement's experiment Remote Sensing and GPS

- GPS, remote sensing - 3 type of „equipment"
- 12 operators - 2 groups: specialists and beginners
- Object: reference parcels and agriculture parcels
- 36 parcels
- Good, medium, bad edge
- Good, medium, bad measurements conditions
- 36 parcels x 12 operators x 3 repetitions x 3 type of „equipment" = 3888 measurements

Two test sites

GPS

Olsztyn
Warmińsko-Mazurskie

Kraków
Małopolskie

Remote Sensing

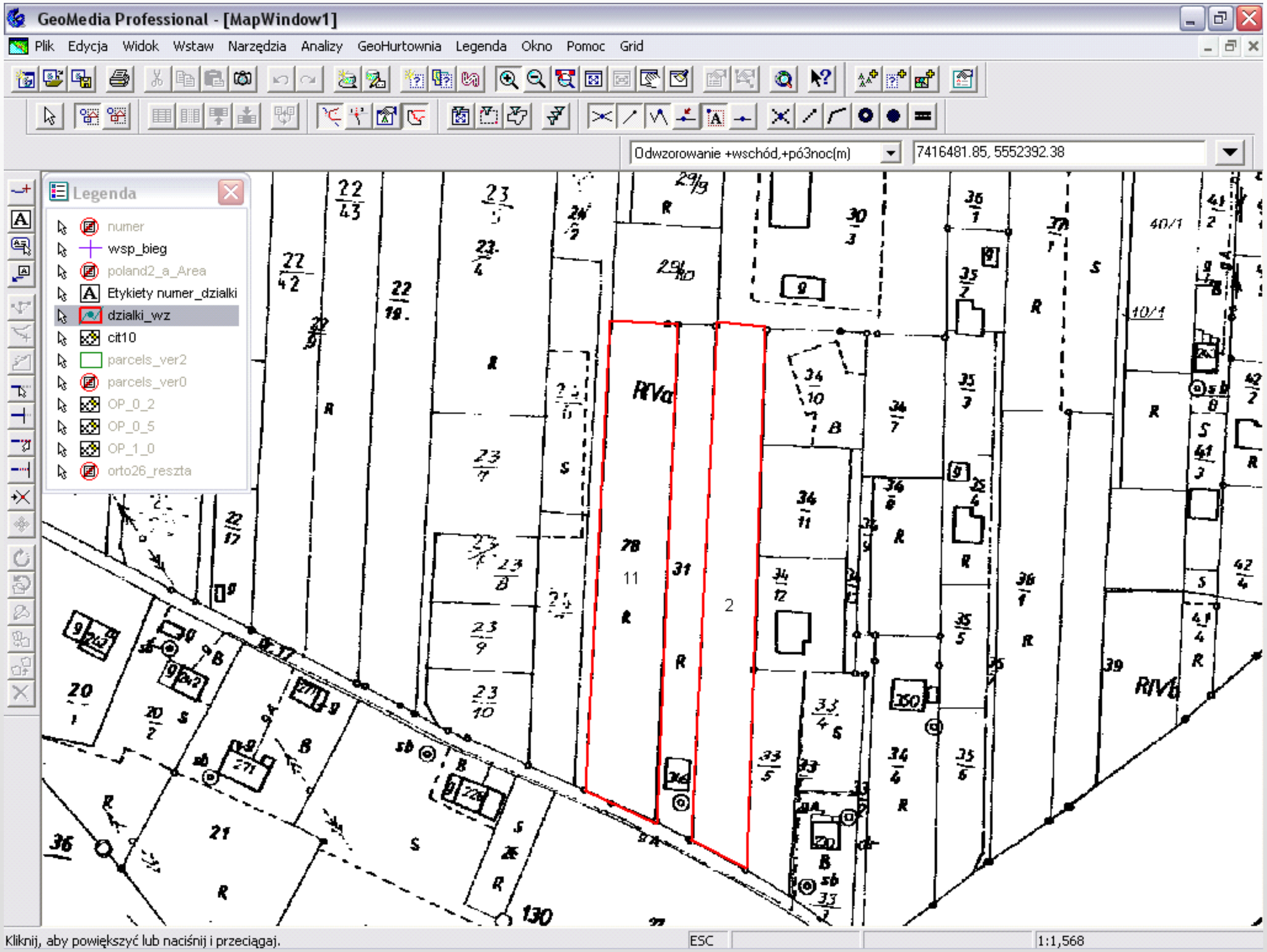
Parcels

- Size
  - S : small (0.3 – 0.5 ha)
  - M : medium (0.8 – 1.2 ha)
  - L : large (2.4 – 4 ha)
- Shape - Shape Factor (SF) = (perimeter/4)^2 / parcel area)
  - S1 : SF < 1:3
  - S2 : SF < 1:6
  - S3 : SF > 1:6
- Border
  - Good
  - Bad

Remote sensing experiment

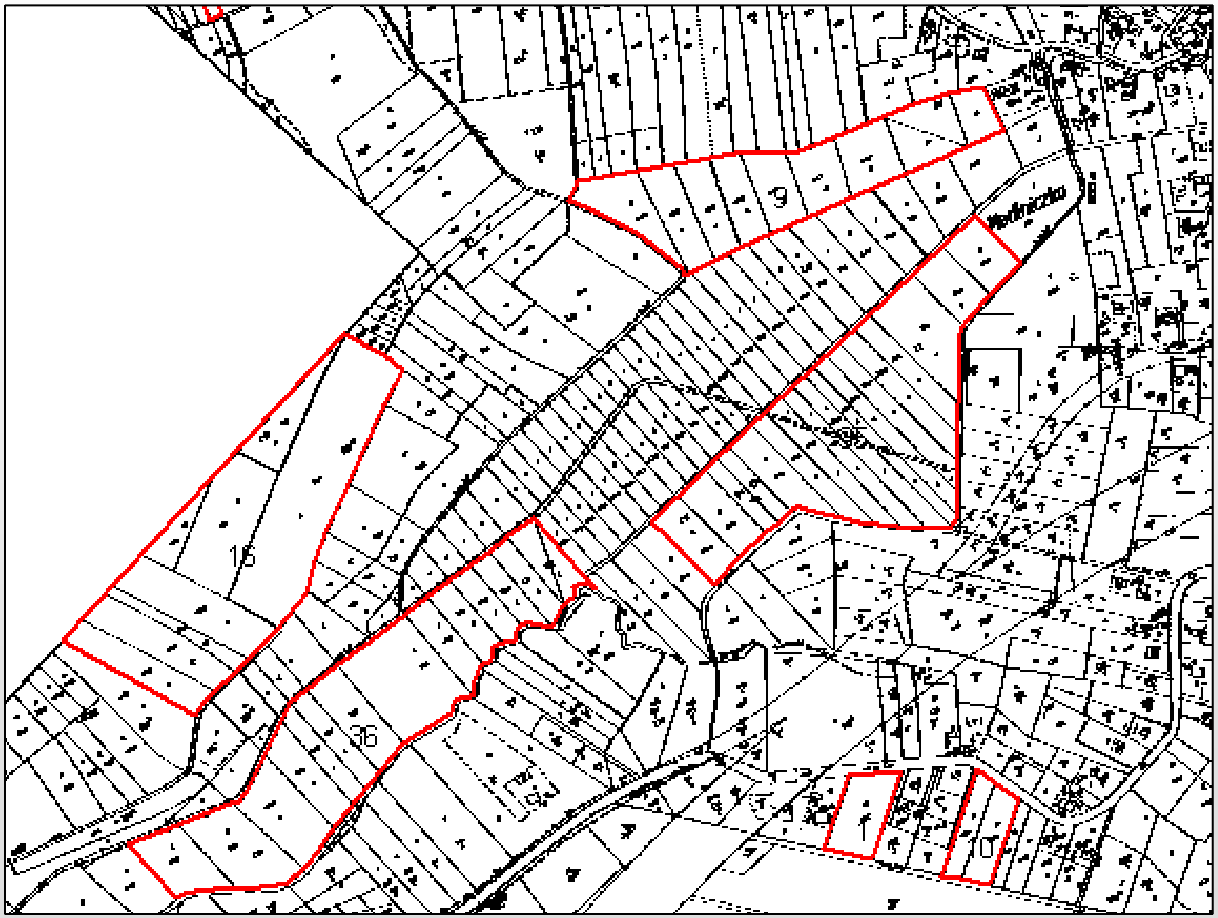
- OP_1_0 IKONOS Panchromatic pixel size 1m
- OP_0_5 Ortohotomap from color images
  - 1: 26 000, pixel size 0.75m
- OP_0_2 Ortophoto from panchromatic images
  - 1:13 000, pixel size 0.25m
  - ARIMR

Reference parcels = cadastre parcels



- One cadastre parcel

Reference parcels = cadastre parcels



- few cadastre parcels

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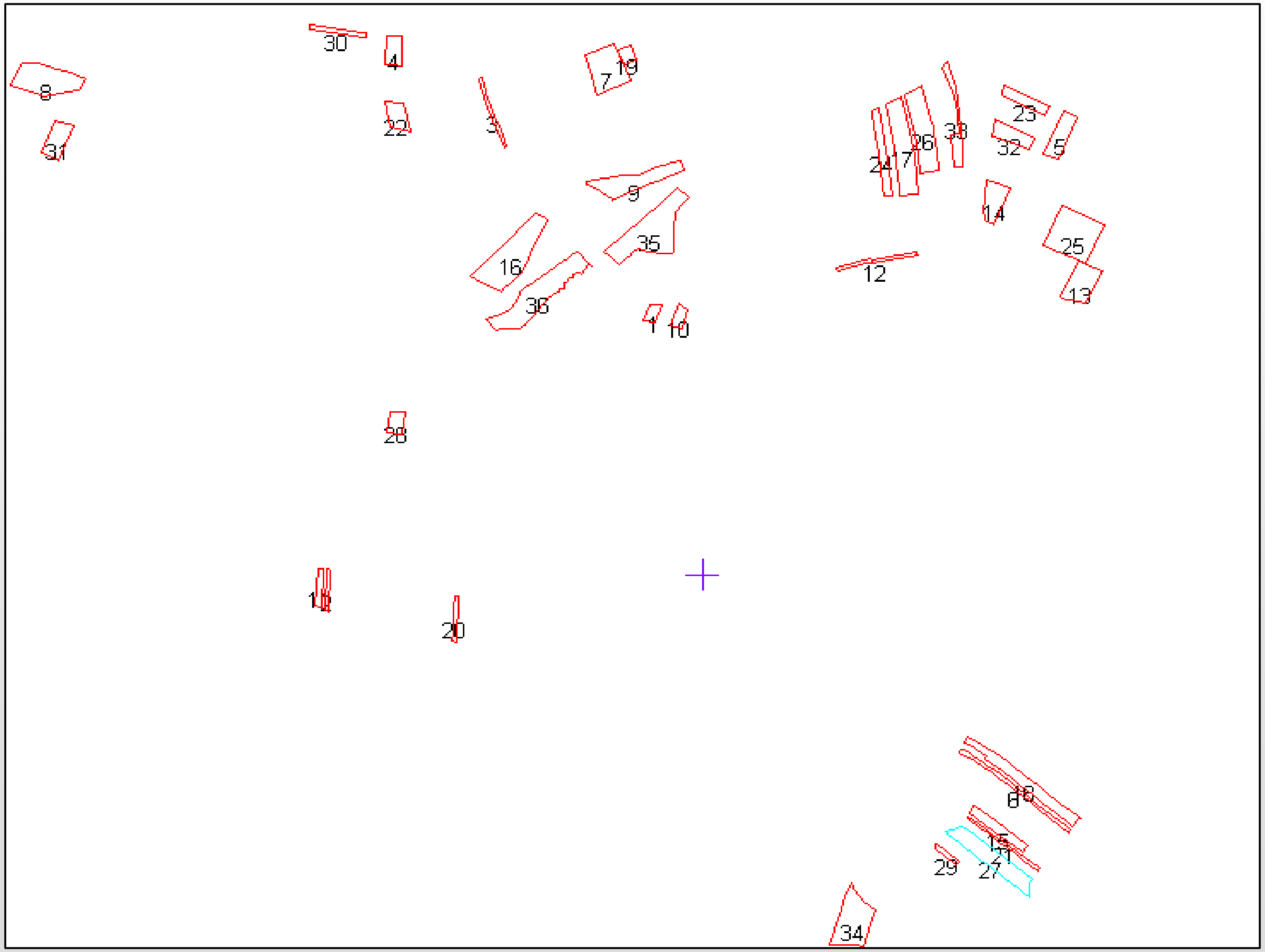
Reference parcels digitized on cadastre raster map



Measurements assumption

- ISO 5725 - especially prepared parcel sequences measured by each operator in all experiment period
- Parcels are independent - not sharing any border with other parcel

International Organization for Standardization

ISO 5725 Accuracy (trueness and precision) of measurement methods and results

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WORKSHEET operators.xls

OPERATOR_1

DAY_1

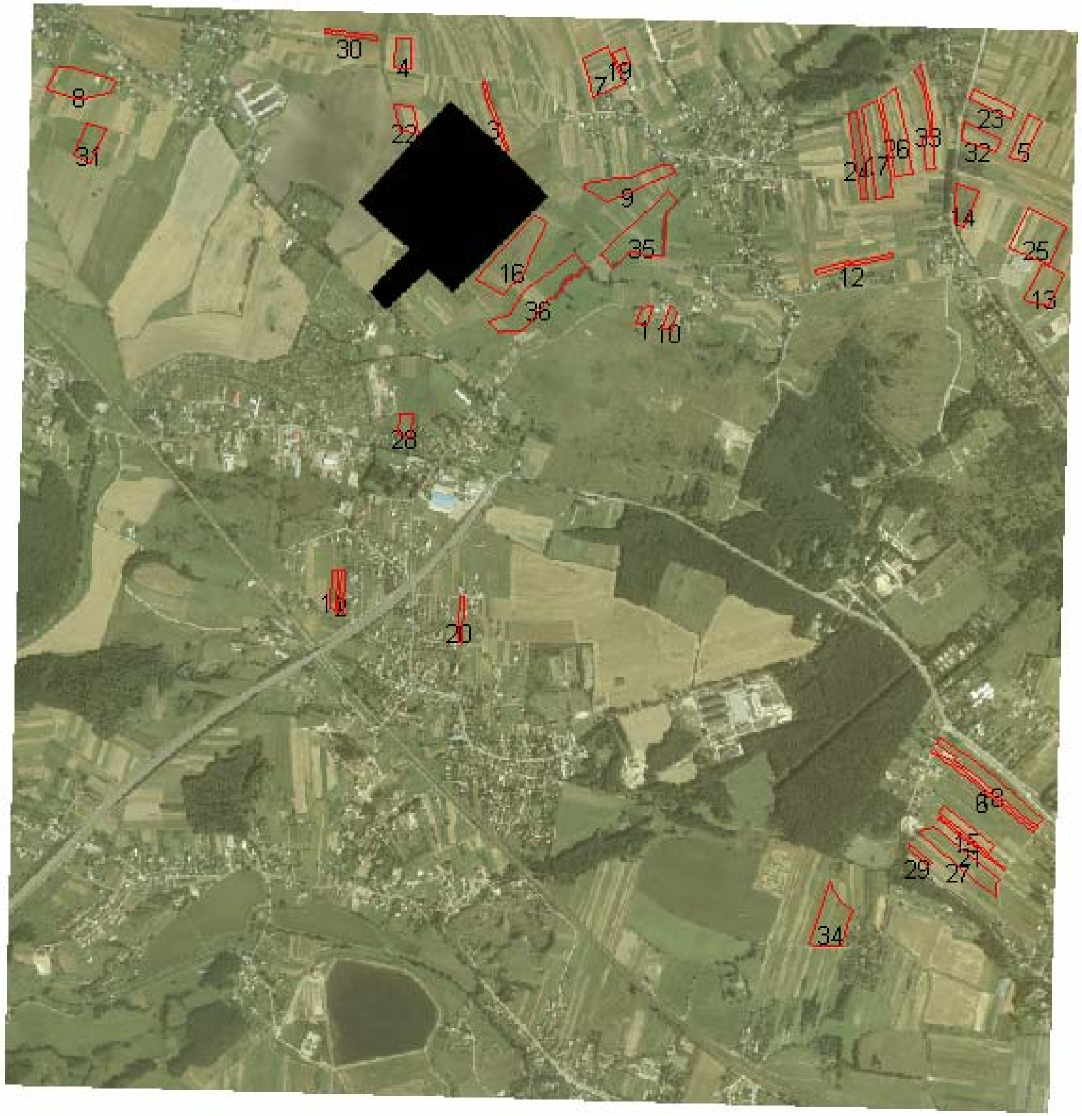
10	OP_1_0
22	OP_0_2
3	OP_0_2
6	OP_1_0
20	OP_0_5
30	OP_0_2
36	OP_1_0
35	OP_0_5
26	OP_0_5
17	OP_0_2
25	OP_0_2
28	OP_0_5
16	OP_0_2
12	OP_0_5
32	OP_1_0
15	OP_1_0
14	OP_1_0
33	OP_1_0
27	OP_0_5
18	OP_1_0
4	OP_0_5
31	OP_1_0
2	OP_0_2
19	OP_0_5
34	OP_0_5
11	OP_0_5
8	OP_0_2
5	OP_0_5
29	OP_1_0
7	OP_1_0
23	OP_1_0
24	OP_1_0
1	OP_0_2
21	OP_0_2
13	OP_0_5
9	OP_1_0

OP_0_2

Airborne photo
1:13000
Pixel – 0.25 m
RMS – 0.75 m

If we assumed:
RMS = 2.5 x piksel size

OP_0_5

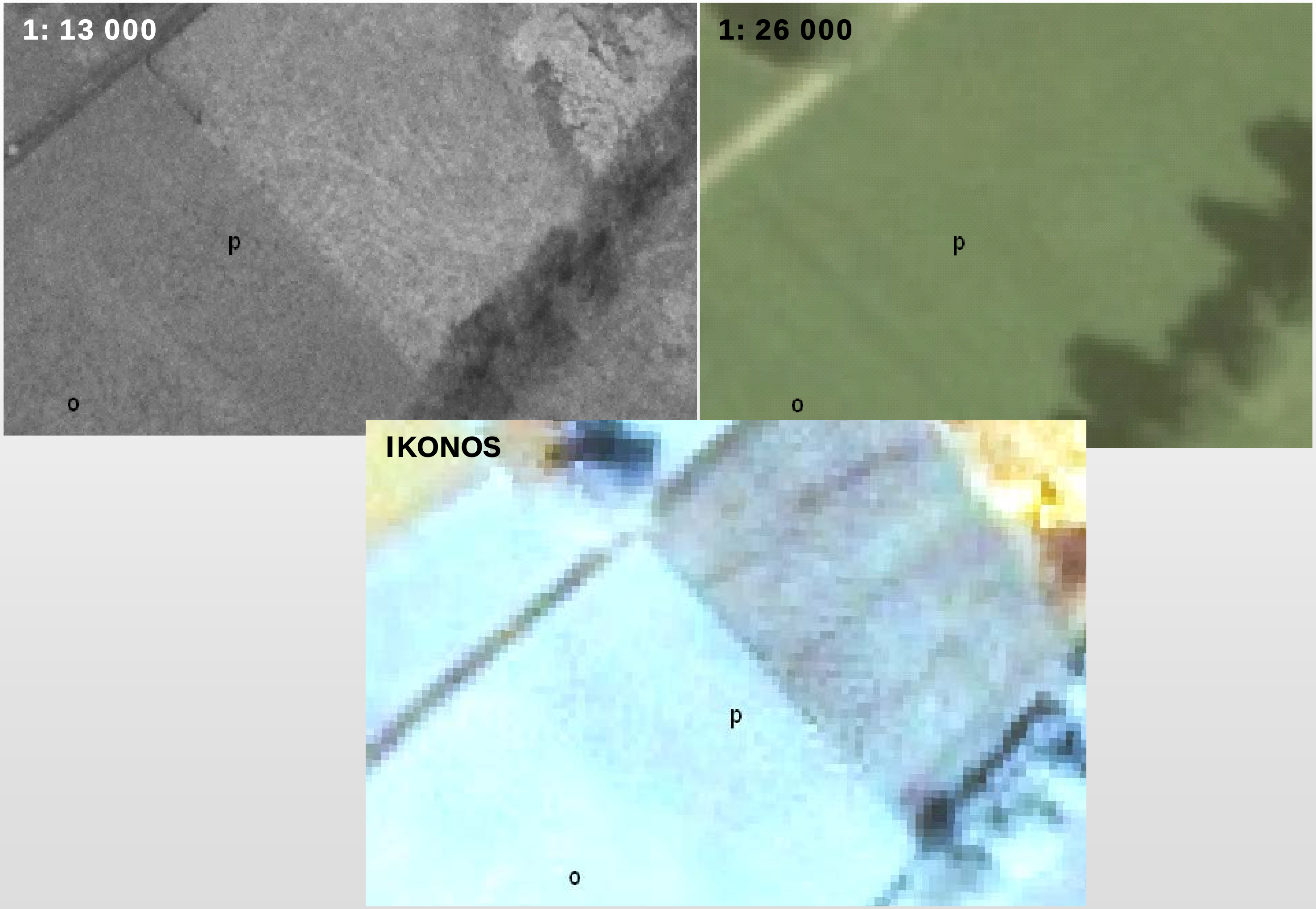


Airborne photo
1:26000
Pixel – 0.5 m
RMS – 1.5 m

OP_1_0

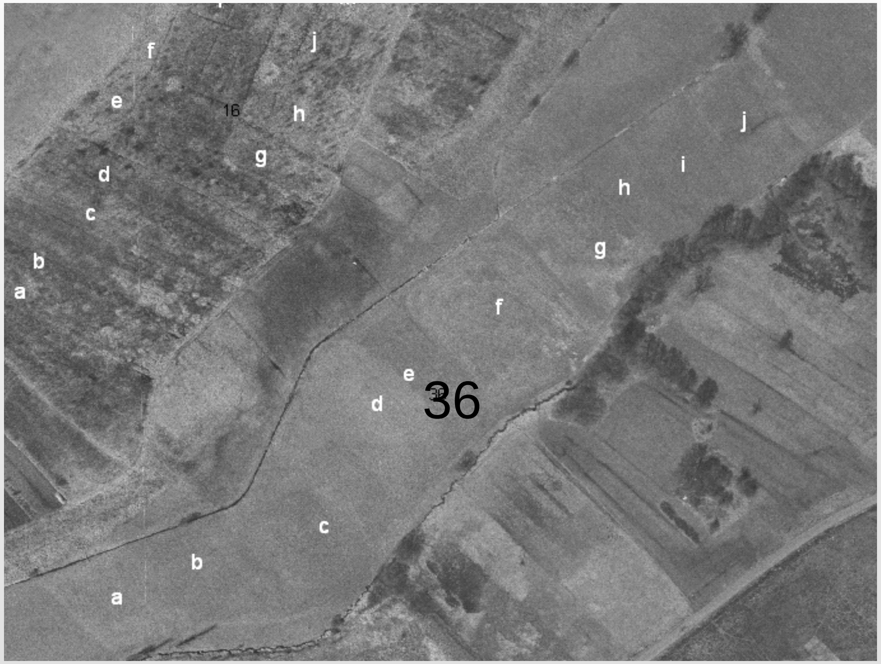
IKONOS
Pansharpening image
1:26000
Pixel – 1.0 m
RMS – 2.5 m

Different parcel border recognition



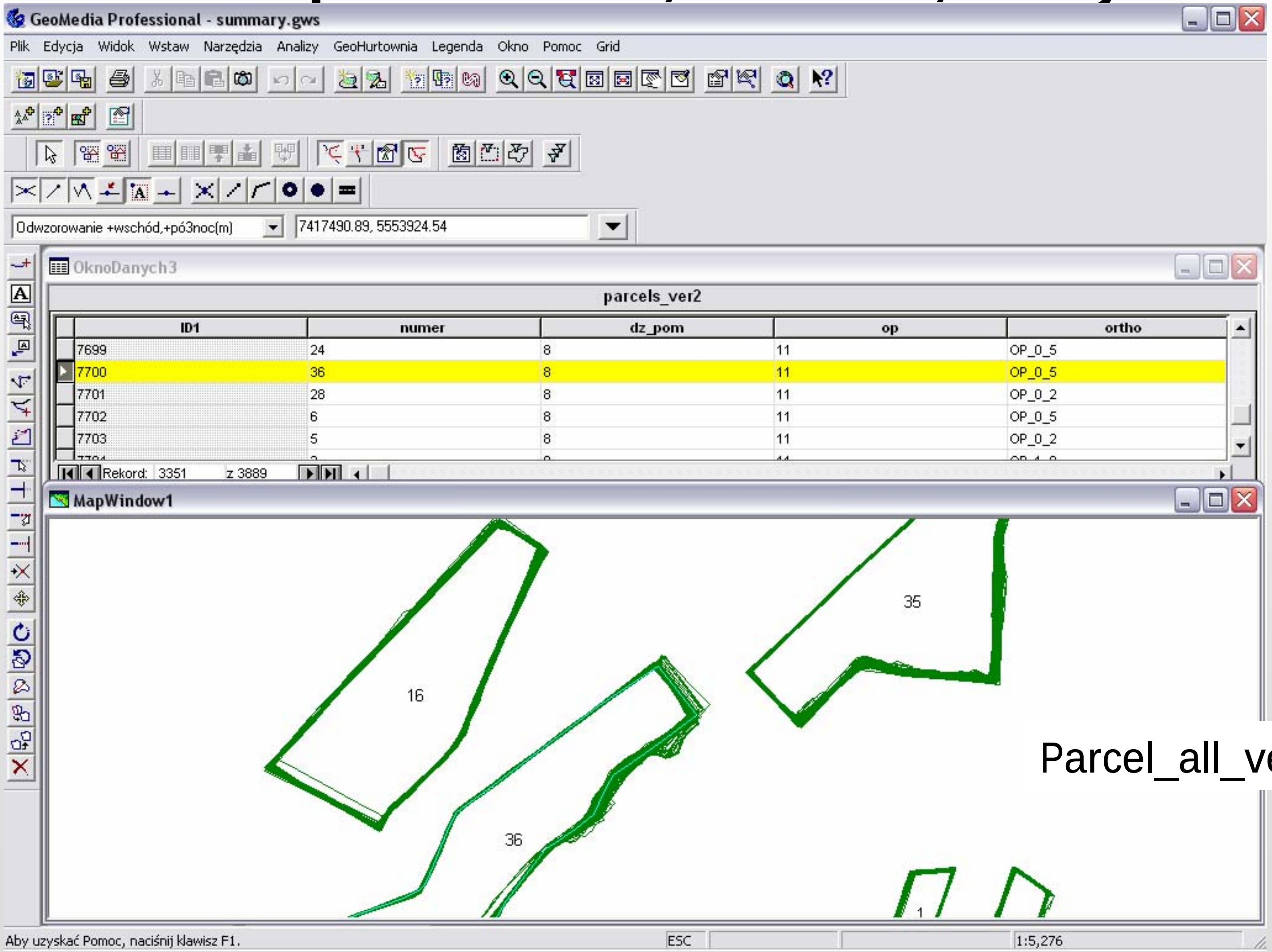
Measurements - workflow

- Measurements using Geomedia (Integraph)
- Each operator
  - list of parcels to be measured on which orto
  - geoworkspace: *.gws,
    - with configured ready to display images
    - number of all parcels (without reference parcels)
    - letters marking parcels building reference parcel



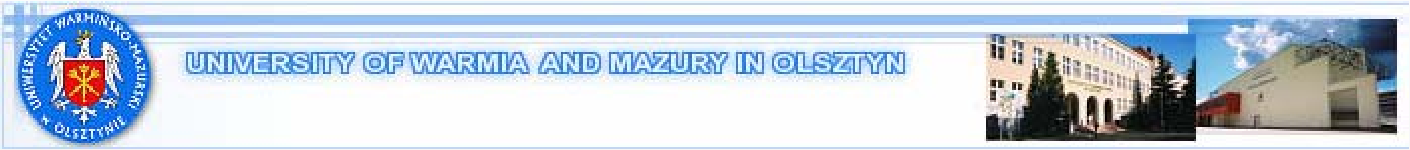
  - warehouse: *.mdb
    - empty feature class – in the feature class operator digitized parcels according list of parcels to be measured on which orto

GIS data base of all measurements: all operators, ortho, days



Parcel_all_ver2.mdb

GPS experiment



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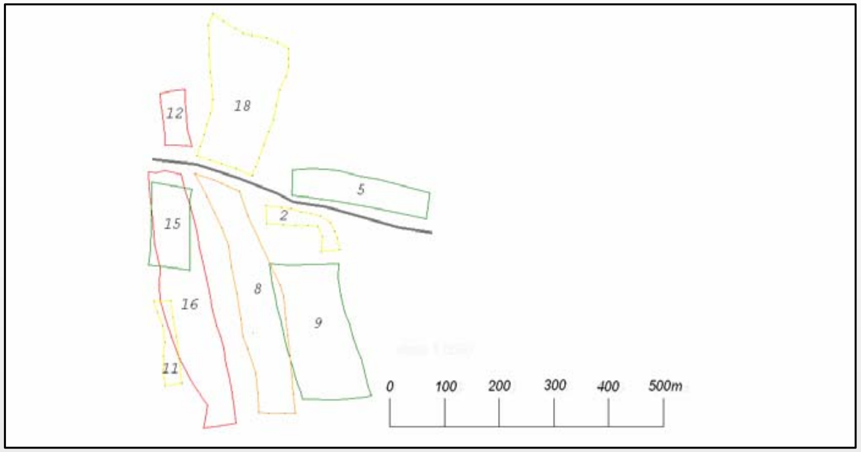
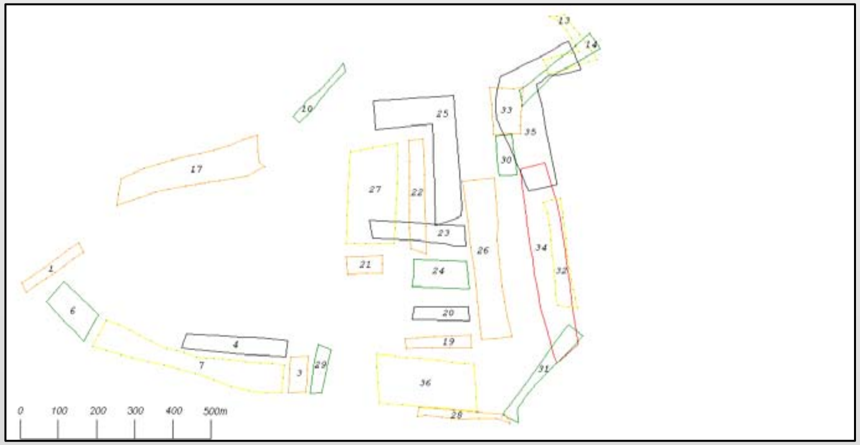
Dr Eng. Adam Ciećko

GPS experiment

- 36 parcels
- 4 Thales Mobile Mapper
- 4 Satcon
- 1 Garmin GPSMap 76S





GPS experiment

- 36 parcels
- 4 Thales Mobile Mapper
- 4 Satcon
- 1 Garmin GPSMap 76S

2250 km of walking!!!

Steps in the statistical analysis

- ISO 5725-2 gives the "basic method for the determination of repeatability and reproducibility of a standard measurement method"
- several land parcels are measured on different days by different operators

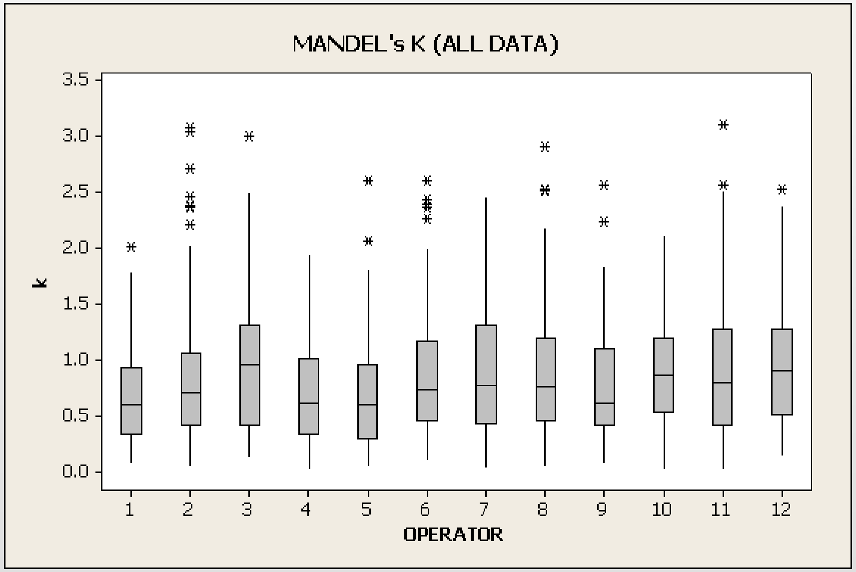
International Organization for Standardization

Establishing a functional relationship between precision values and the characteristics of the parcels

INITIAL DATA PROCESSING

Statistical tools for critical examination of the data

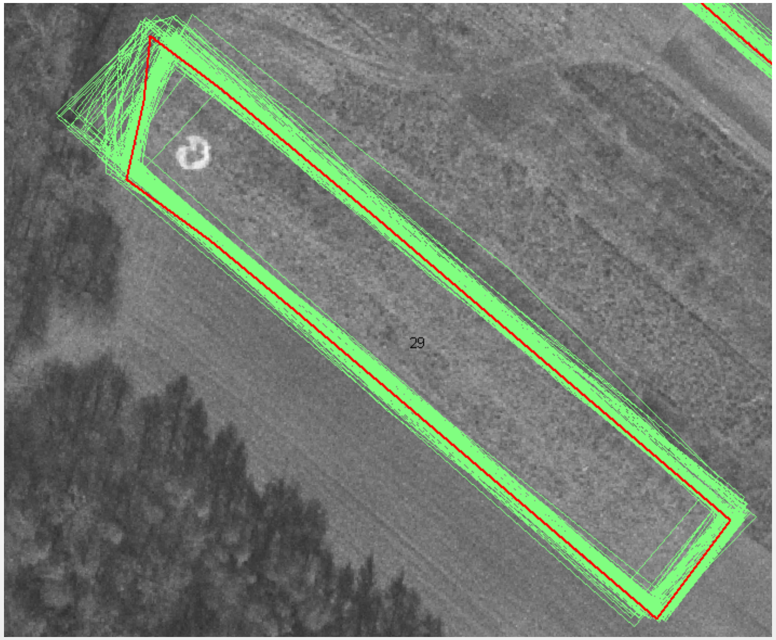
- Mandel's h and k statistics
- Cochran's test
- Grubbs' test for one outlying observation
- Grubbs' test for two outlaying observations



RESULTS

Standard deviation of the parcel area (m_p)

RS experiment



__Point Position Method__

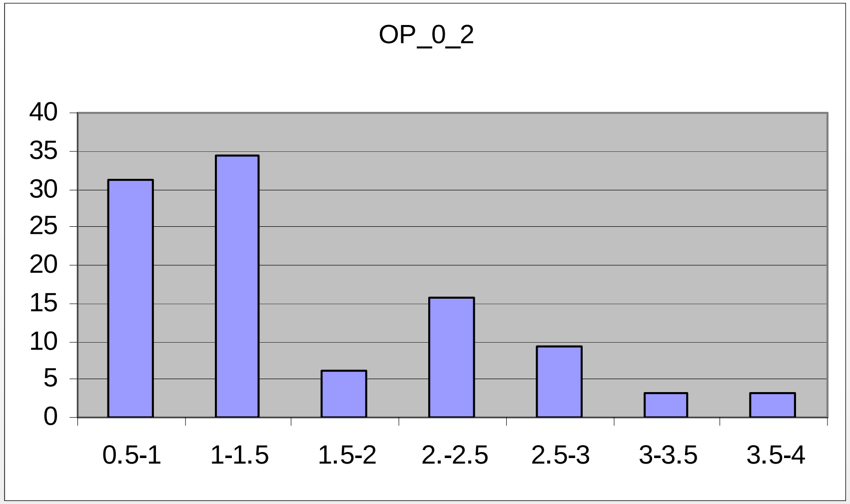
$m_p = m_{pkt} * AEC$
$m_p = StD$
$m_{pk} = StD/AEC$

__Buffer Method__

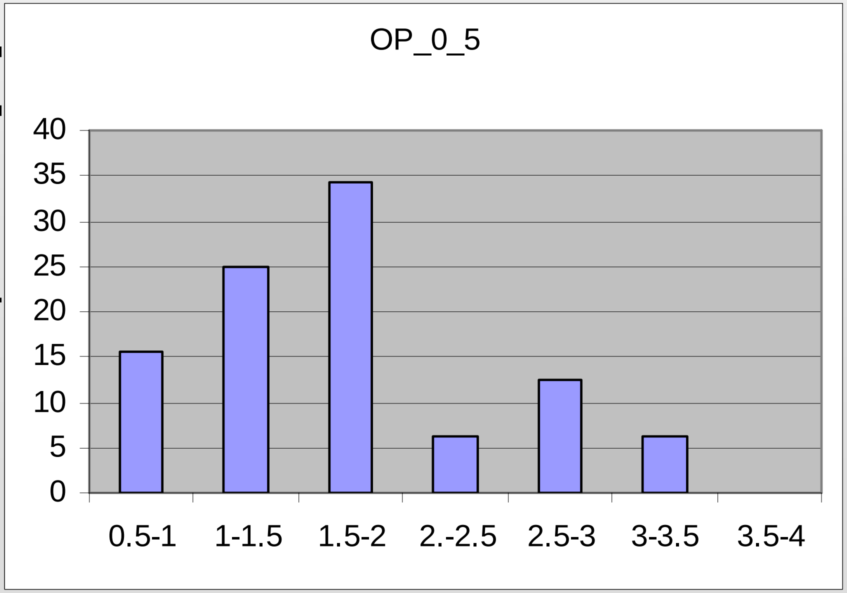
Buffer Area = Buffer * Perimeter
Buffer Area = StD
Buffer = StD/Perimeter

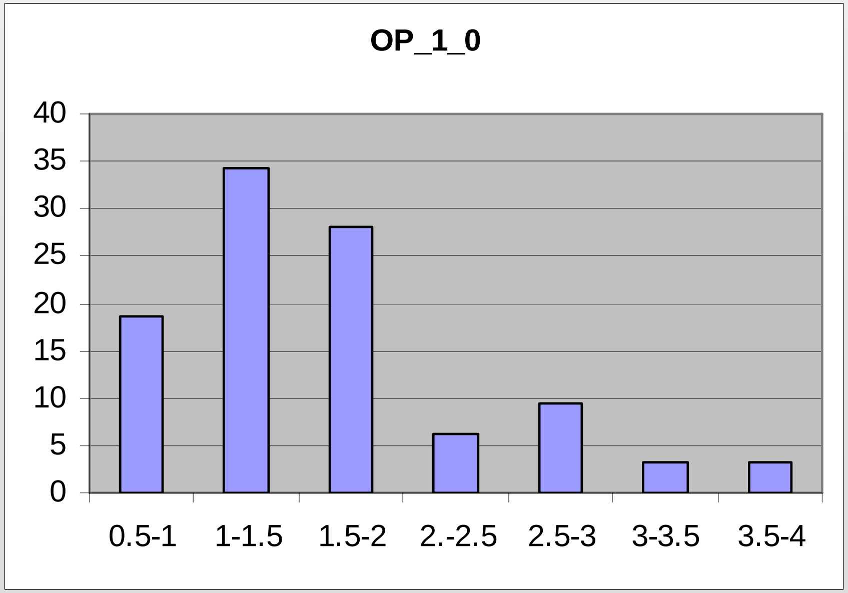
RS experiment

- Value of buffer:
  - OP_0_2 – 0.37m +/- 0.26m
  - OP_0_5 – 0.44 m +/- 0.25m
  - OP_1_0 – 0.44 m +/- 0.33m
- Value of point position error:
  - OP_0_2 – 1.86m +/- 1.85m
  - OP_0_5 – 2.14 m +/- 1.39m
  - OP_1_0 – 2.12 m +/- 1.65m



Amount of parcels [%]

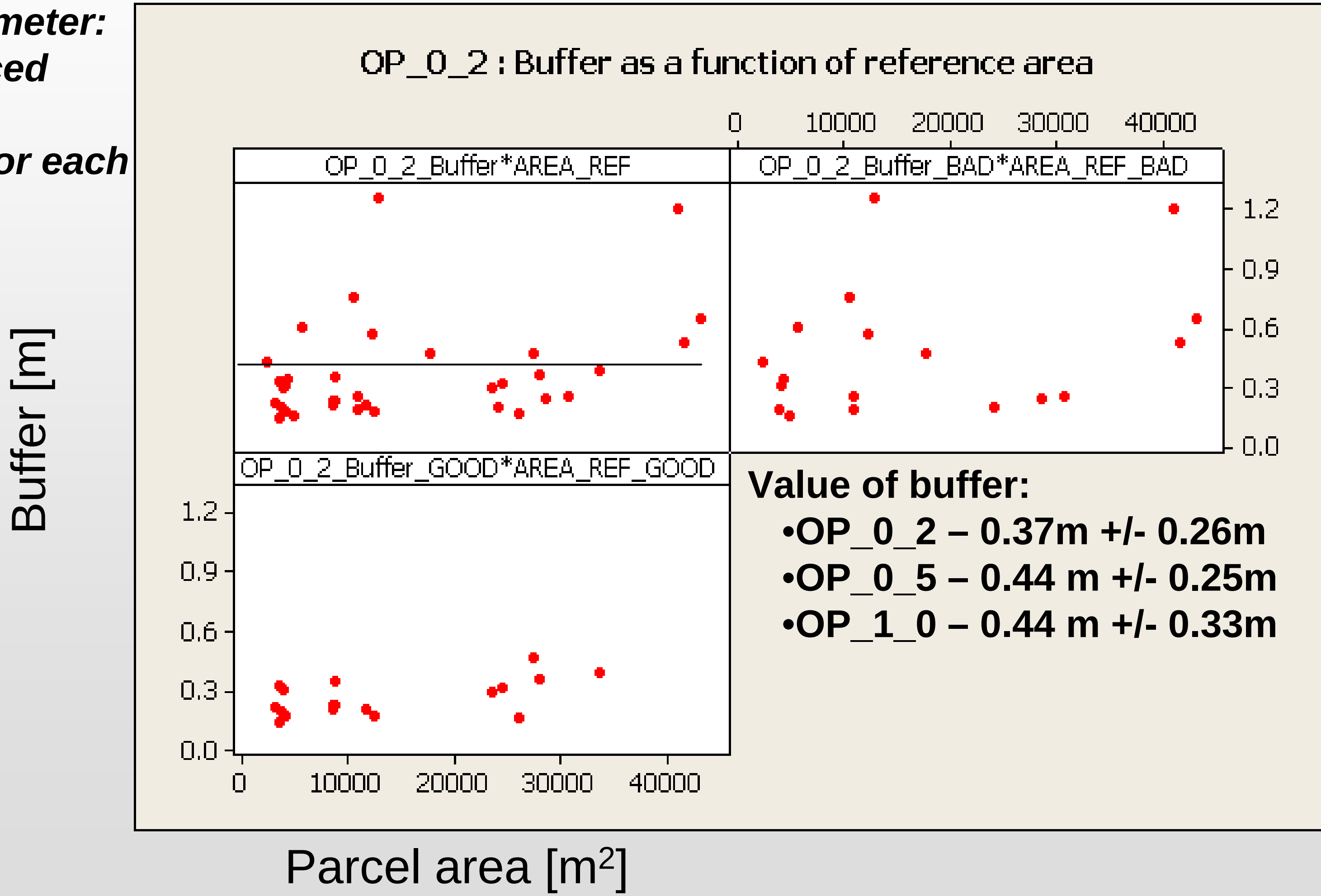




Point position error [m]

RS buffer

Parcel area error parameter:
- ***shouldn't be influenced by area***
- ***should be constant for each ortophoto***

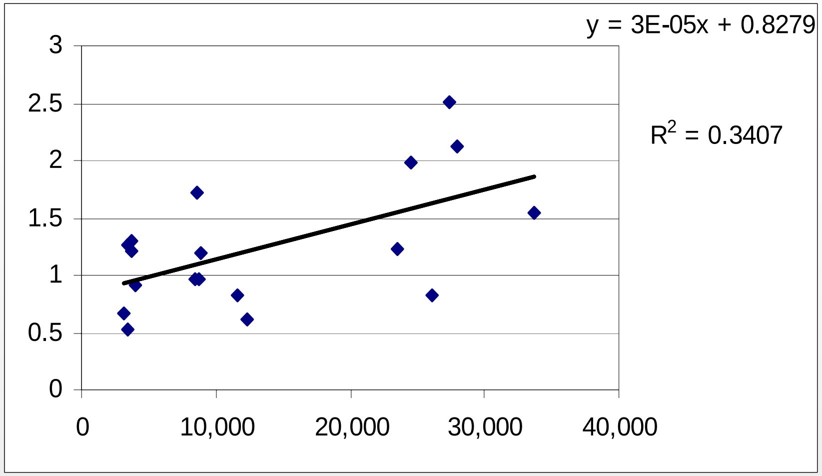


Value of buffer:
- **OP_0_2 – 0.37m +/- 0.26m**
- **OP_0_5 – 0.44 m +/- 0.25m**
- **OP_1_0 – 0.44 m +/- 0.33m**

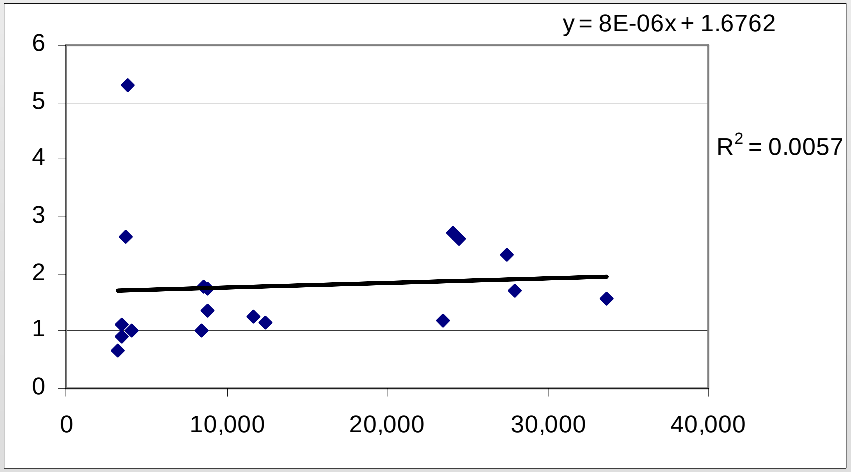
RS point position error

Point position error [m]

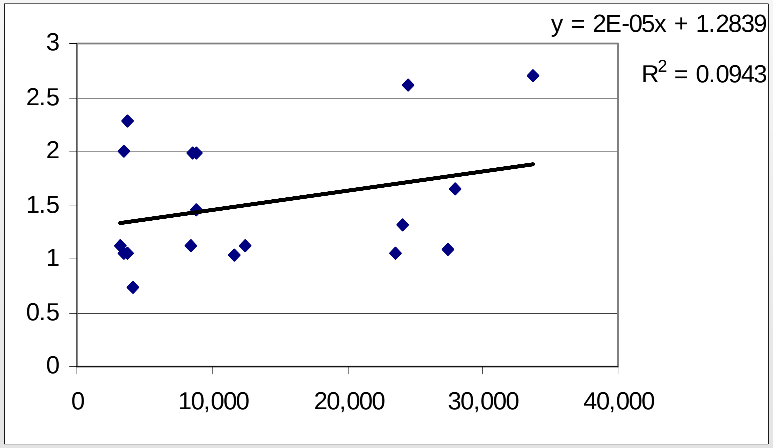
OP_0_2



OP_0_5



OP_1_0



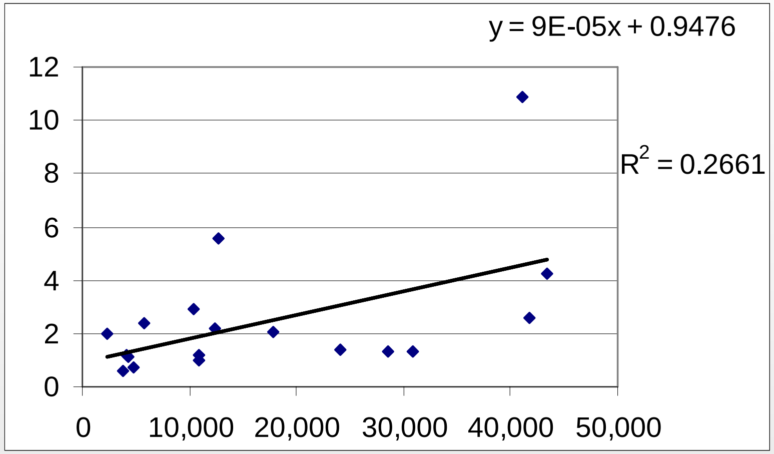
Good border

Parcel area [m^2]

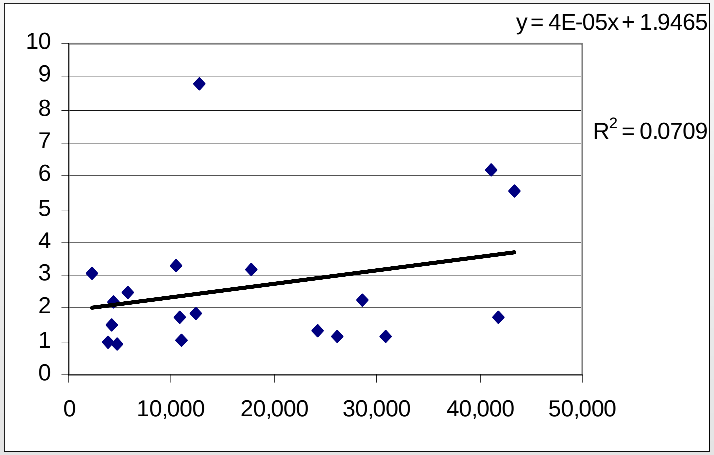
RS point position error

Point position error [m]

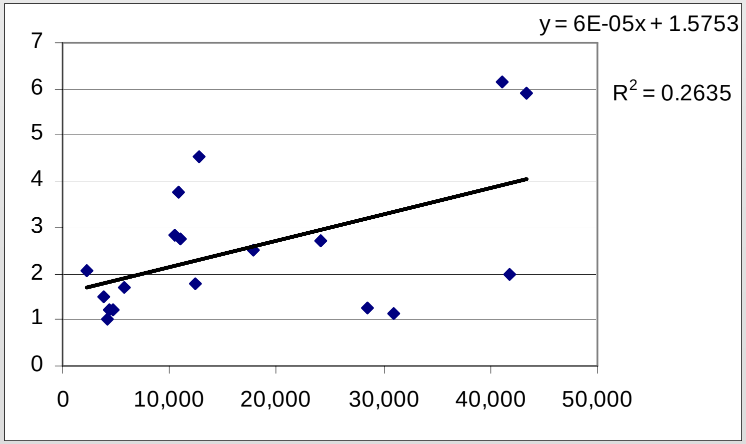
OP_0_2



OP_1_0



OP_0_5

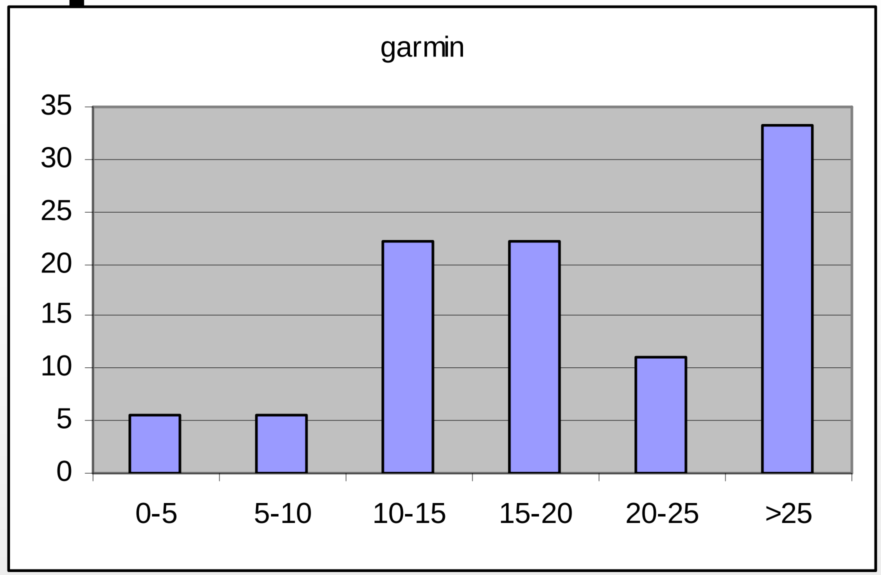


Bad border

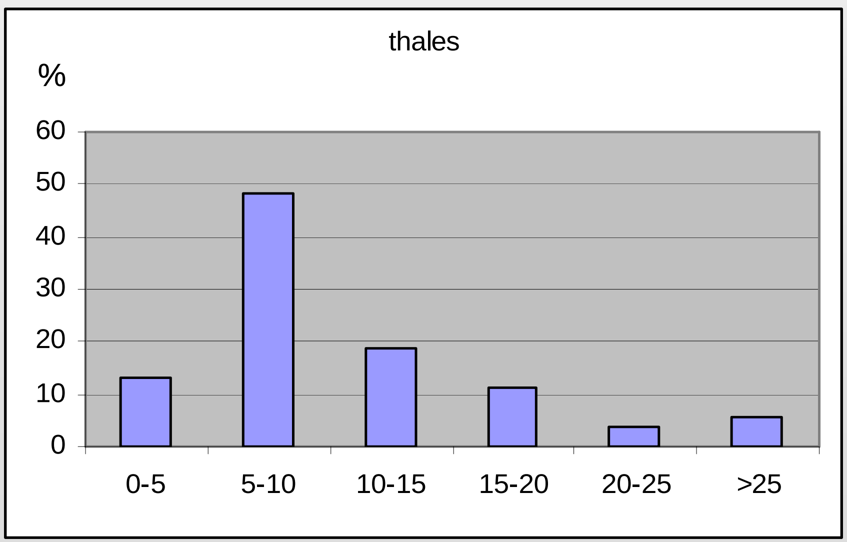
Parcel area [m^2]

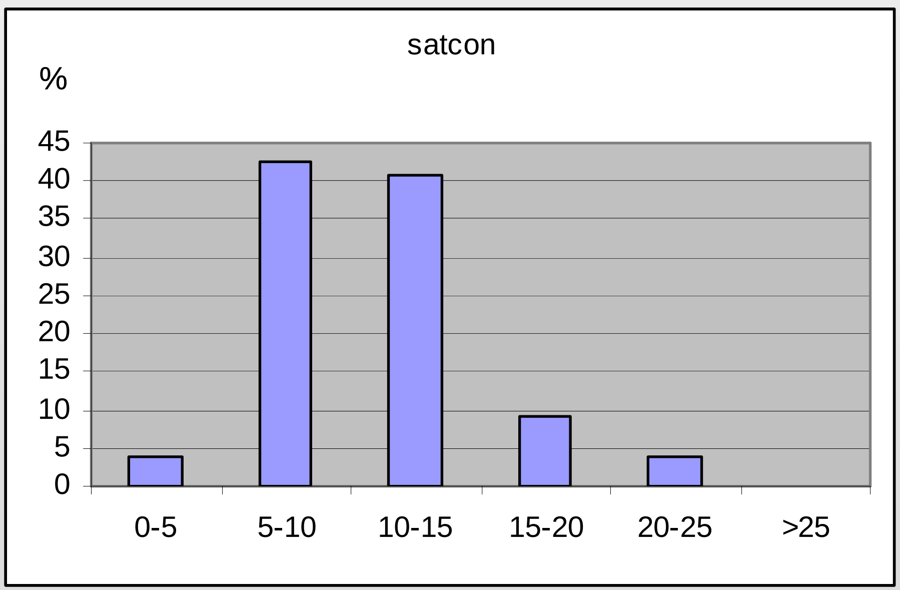
GPS experiment

- Value of buffer:
  - Garmin: 0.76m +/- 0.32 m
  - Satcon: 0.34m +/- 0.08m
  - Thales: 0.52m +/- 0.34m
- Value of point position error:
  - Garmin: 21m +/- 11 m
  - Satcon: 9 m +/- 3 m
  - Thales: 14 m +/- 10m



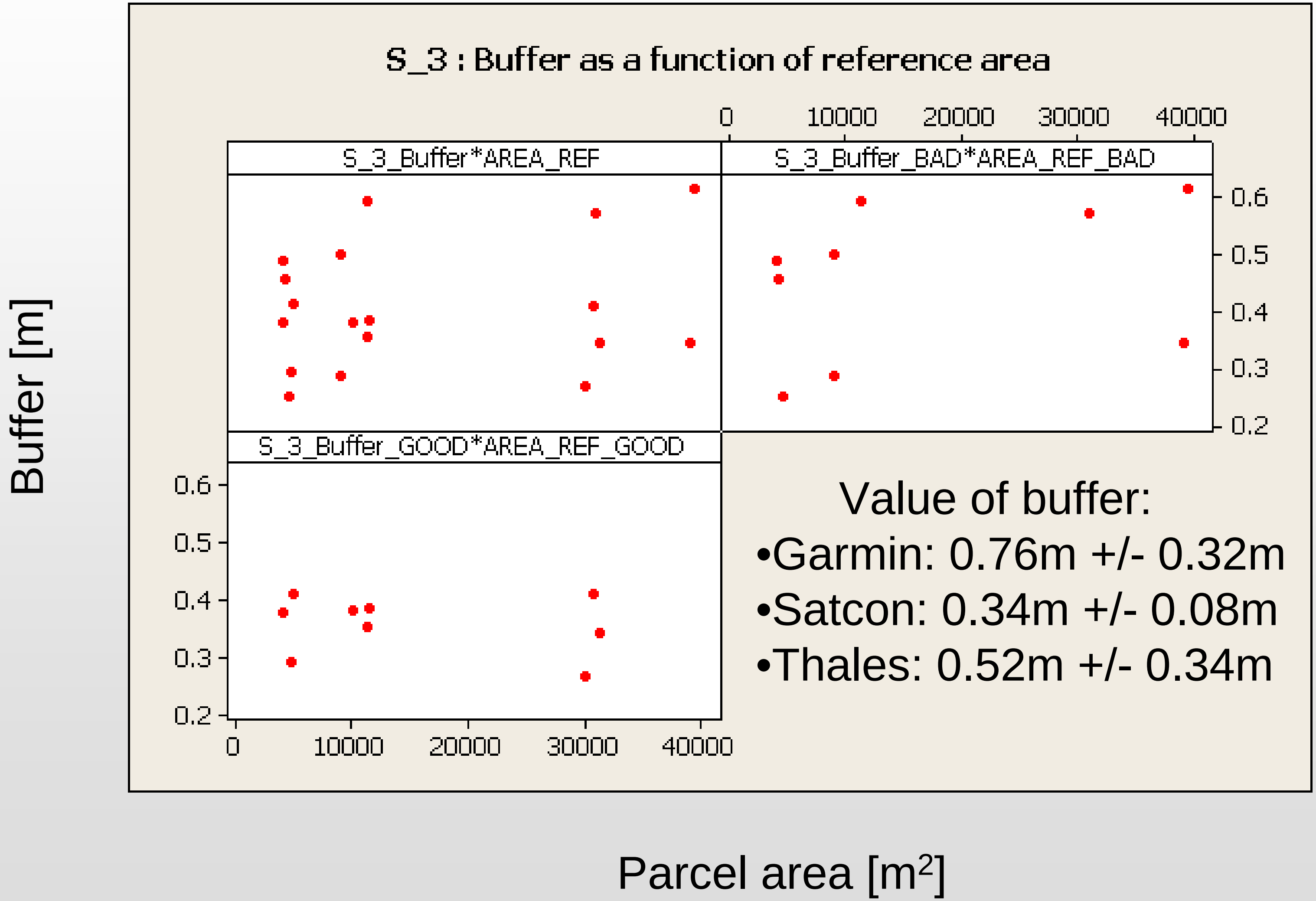
Amount of parcels [%]





Point position error [m]

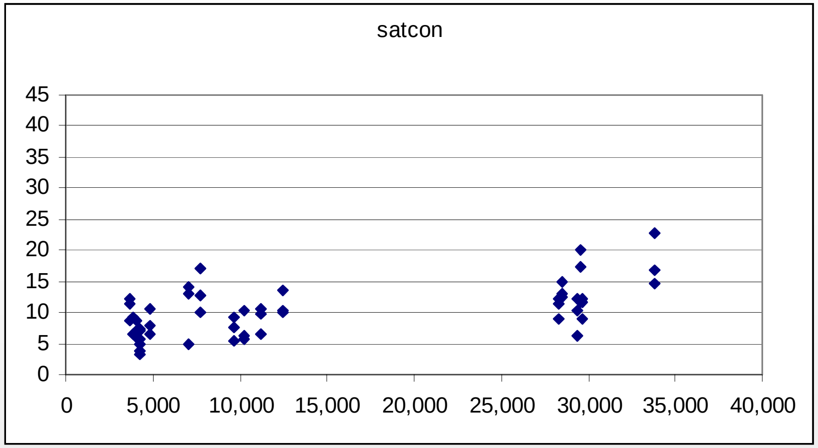
GPS buffer

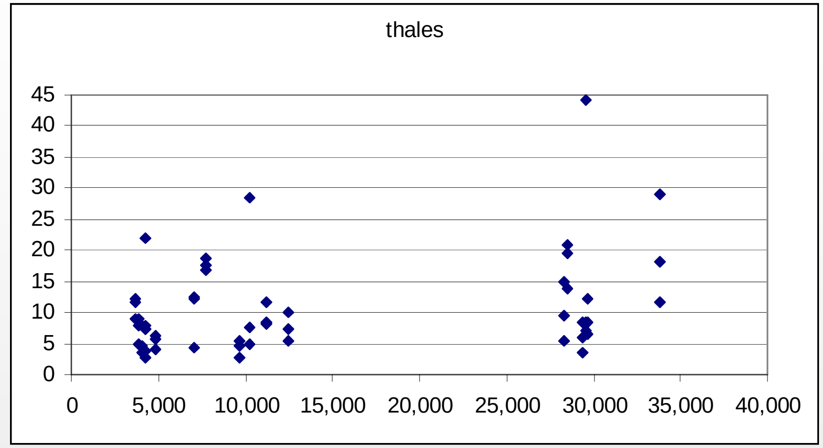


Value of buffer:

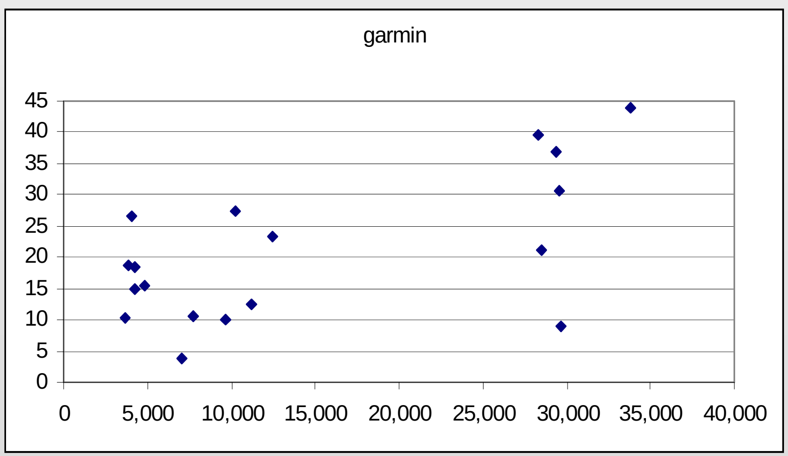
- Garmin: 0.76m +/- 0.32m
- Satcon: 0.34m +/- 0.08m
- Thales: 0.52m +/- 0.34m

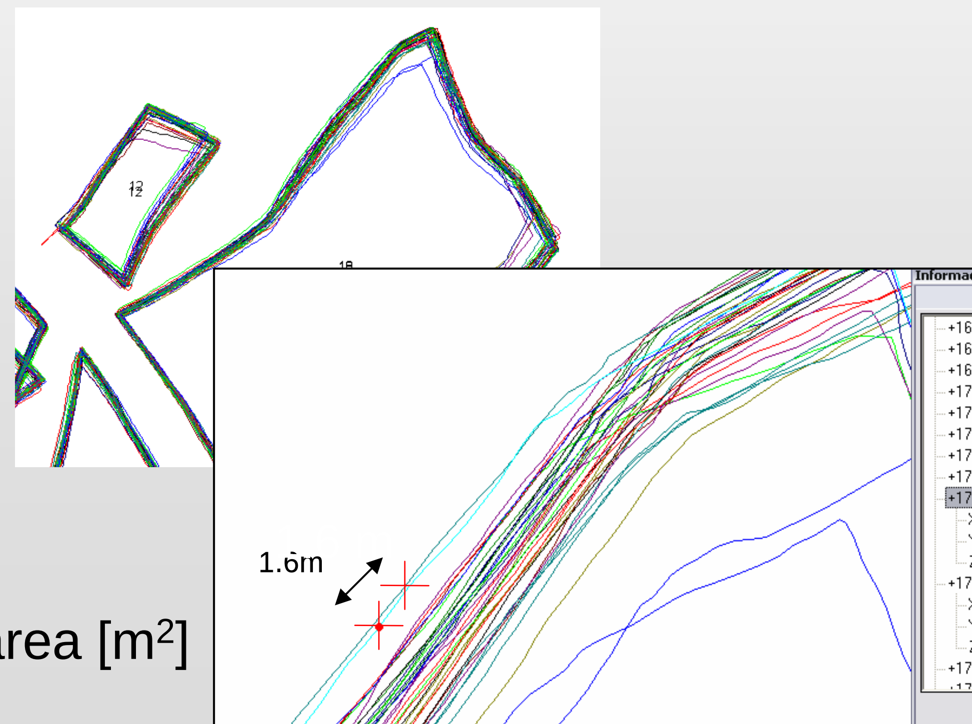
GPS point position error





Point position error [m]





Parcel area [m^2]

Buffer for all measurements

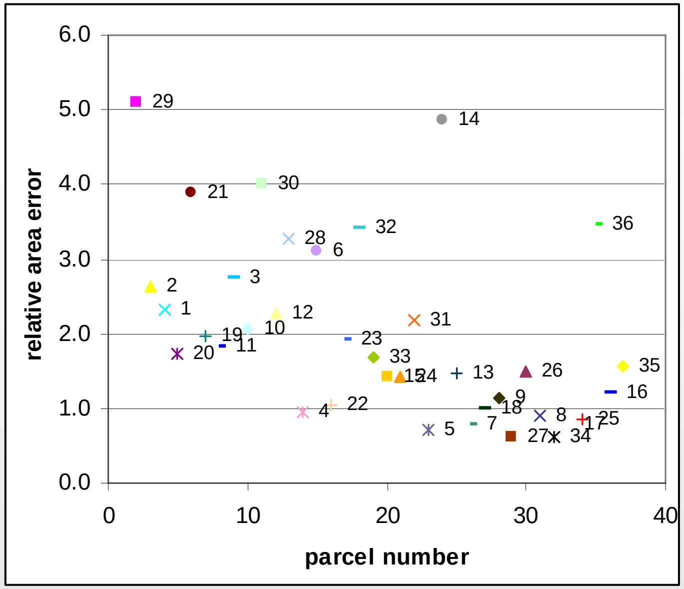
Ortho	Buffer [m]	Standard deviation [m]	Relative area error (%)
OP_0_2	0.37	0.26	3.2
OP_0_5	0.44	0.25	6.3
OP_1_0	0.44	0.33	5.4
Garmin	0.76	0.32	4.9
Satcon	0.34	0.08	2.6
Thales	0.52	0.34	3.7
Satcon S3	0.41	0.11	2.5 (42)
Satcon S4	0.36	0.12	2.3 (21)
Thales T3	0.34	0.16	2.3 (2.4)
Thales T4	0.31	0.13	2.7 (2.2)
average	0.429	0.21	3.6

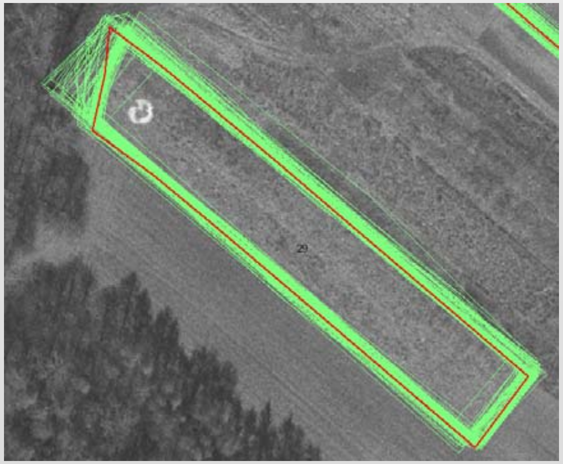
Point position error on the basis of the real measurements

Ortho	m_{pkt} [m]	Standard deviation [m]
OP_0_2	1.86	1.85
OP_0_5	2.14	1.39
OP_1_0	1.89	1.78
average	**2.04**	**1.63**

Equipment	m_{pkt} [m]	Standard deviation [m]
Garmin	11	11
Satcon	9	3
Thales	14	10
Satcon S3	11	5
Satcon S4	10	4
Thales T3	10	6
Thales T4	9	5
average	**12**	**6**

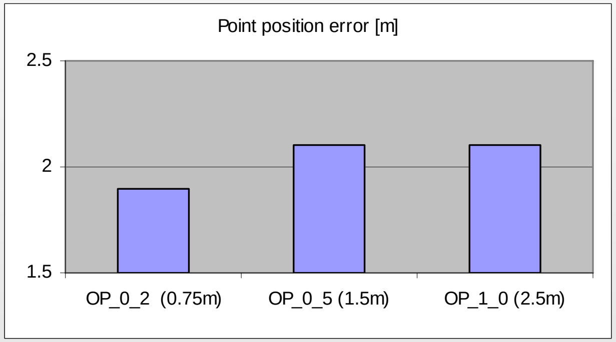
GIS analysis





Main study RS summary

- Data
  - aerial from photos: 1: 13 000 (panchromatic), 2004
    pixel size 0.2m, RMS=0.75m
  - aerial from photos: 1: 26 000 (color), 1999 (or earlier)
    pixel size 0.75m, RMS=1.5m
  - IKONOS (pansharpening), 2004
    pixel size 1m, RMS=2.5m



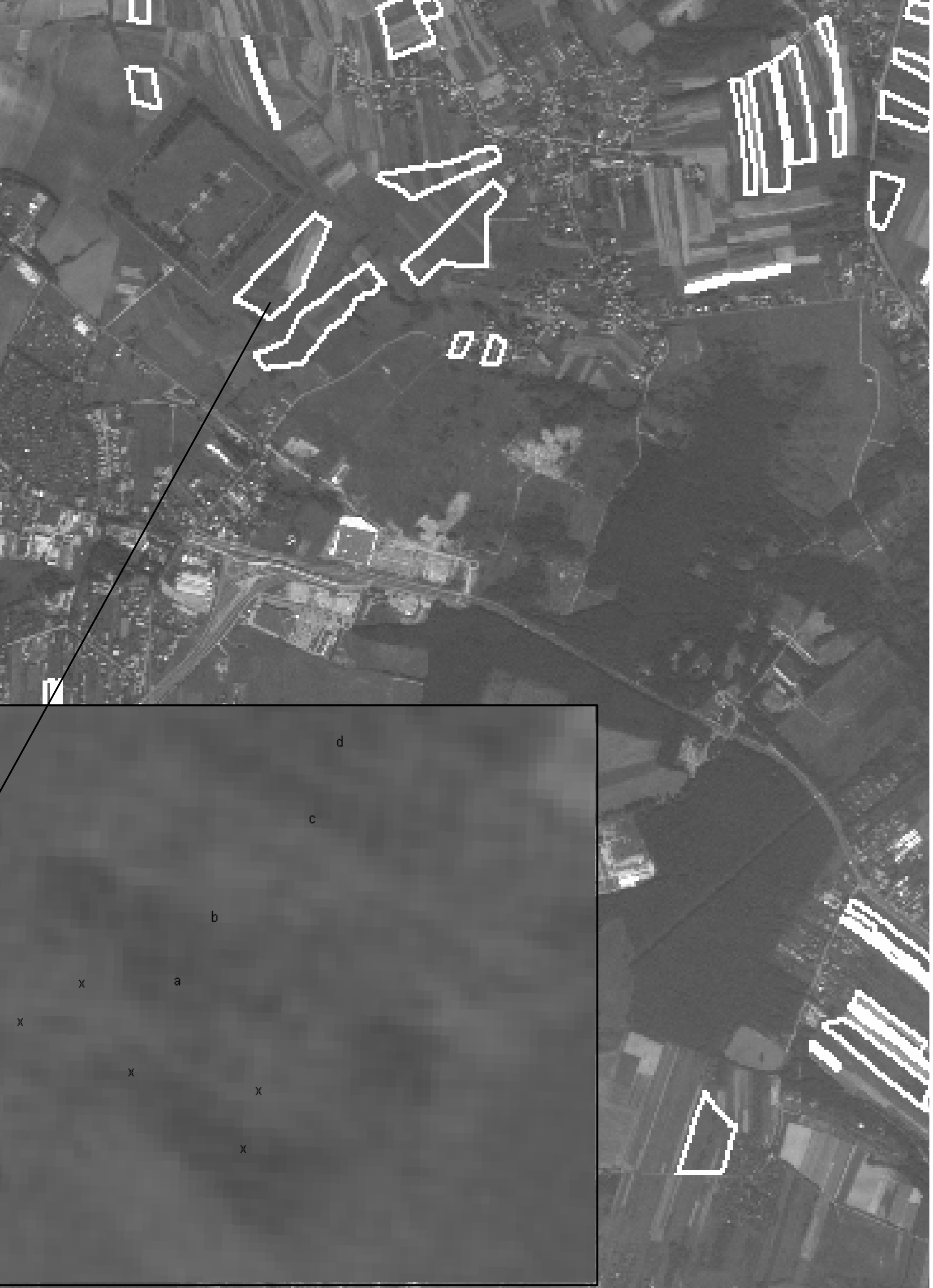
- Results
  - area error is only slightly increasing with increasing pixel size
  - area measurements are not influenced by operator (skilled and unskilled provide similar results)
  - buffer is less influenced by parcel area in compare to point position error (PPM could easy apply for parcel area prediction)

Plan of measurement’s experiment supplementary study

- Remote sensing - 2 type of „equipment”
- 6 operators
- 36 parcels - almost the same parcel sets (one parcel was changed - clouds)
- 1296 observations = 36 parcels × 2 photos × 6 operators × 3 days
- The same workflow of measurements

Images

- RS data were obtained from JRC and orthofotomap were generated at AGH UST Kraków, Poland:
  - Panchromatic ortofotomap generated from SPOT image (3m):
    - Registered: 29.08.2005
    - With pixel size: 2.5 m
  - Panchromatic ortofotomap generated from EROS image (2m)
    - Registered: 3.07.2005
    - With pixel size: 2.0 m


d
c
b
x
a
x
x
x
x


d
c
b
x
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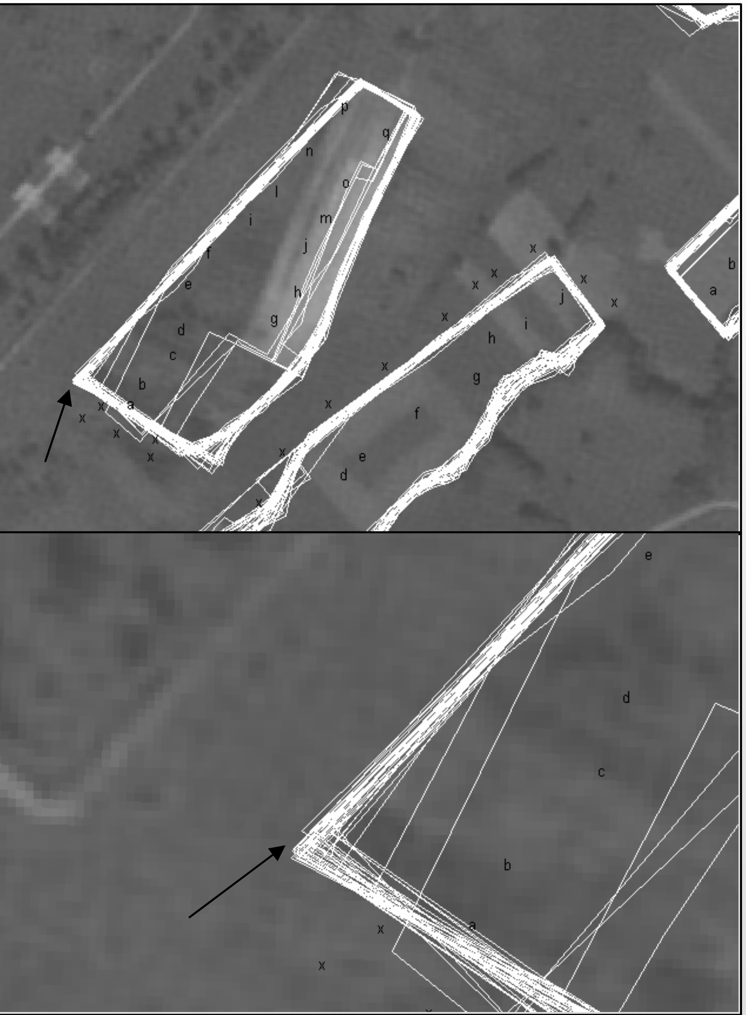
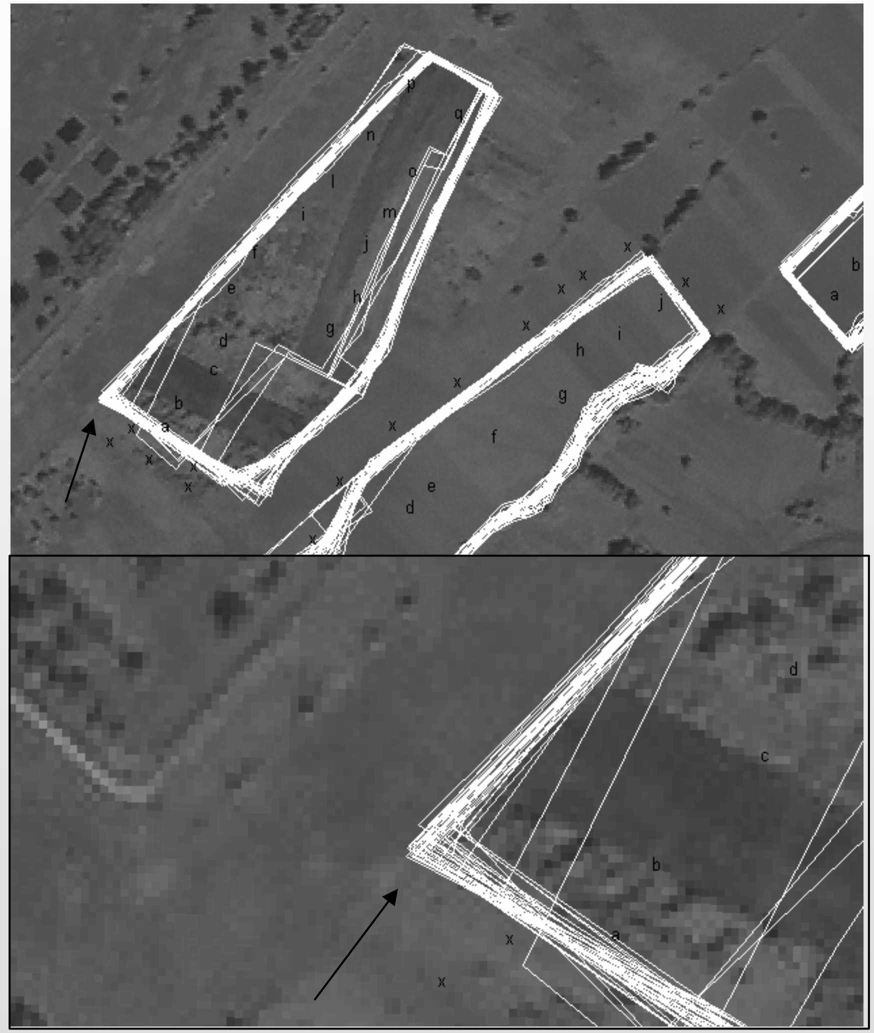
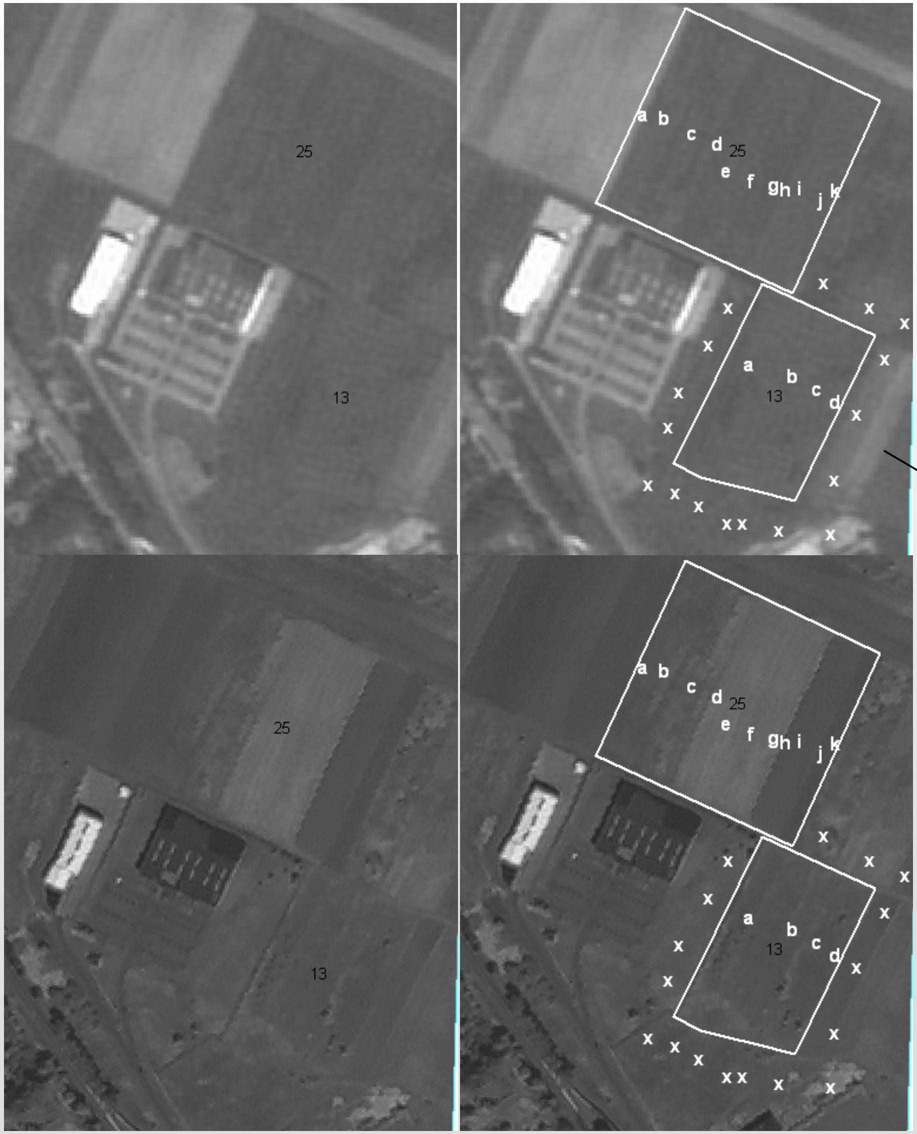
x
x
x
x

RS supplementary study

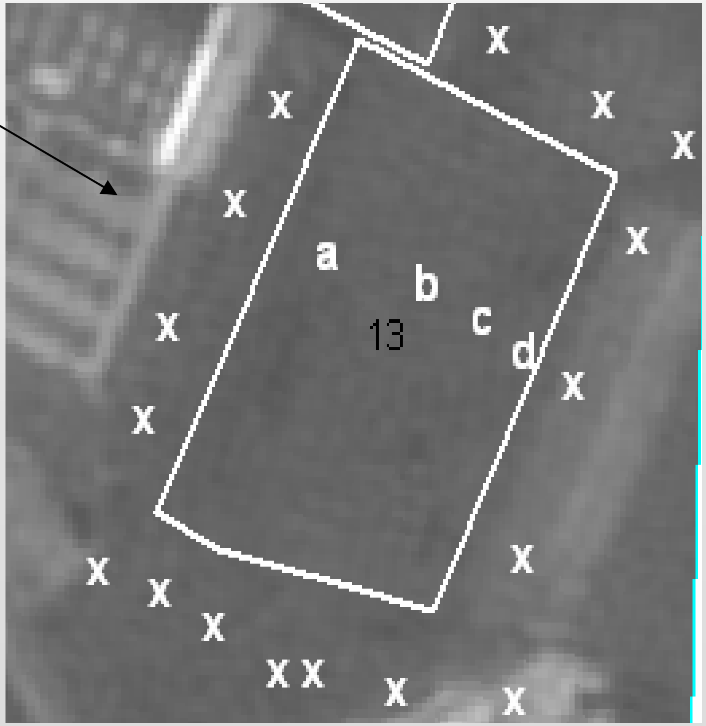




RS supplementary study



Additional marks showing parcels not belonging to the measured parcel



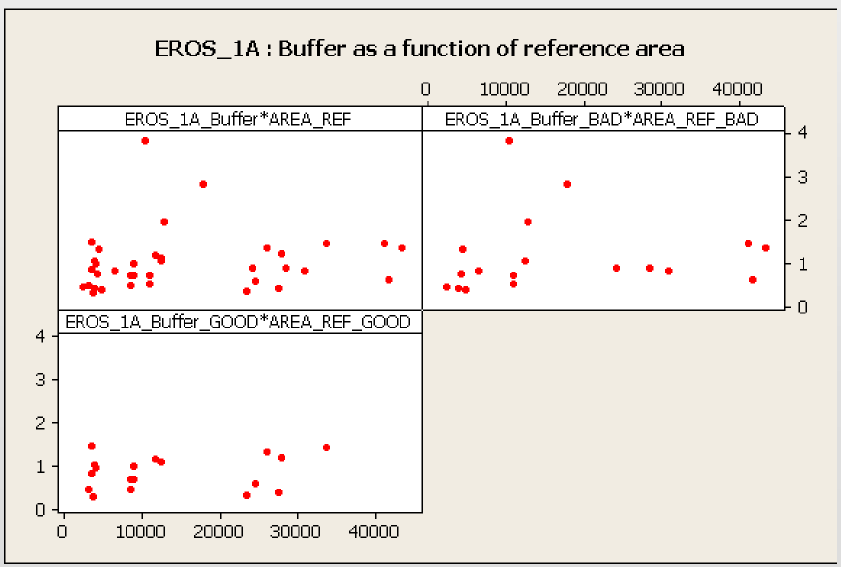
Modelling buffer

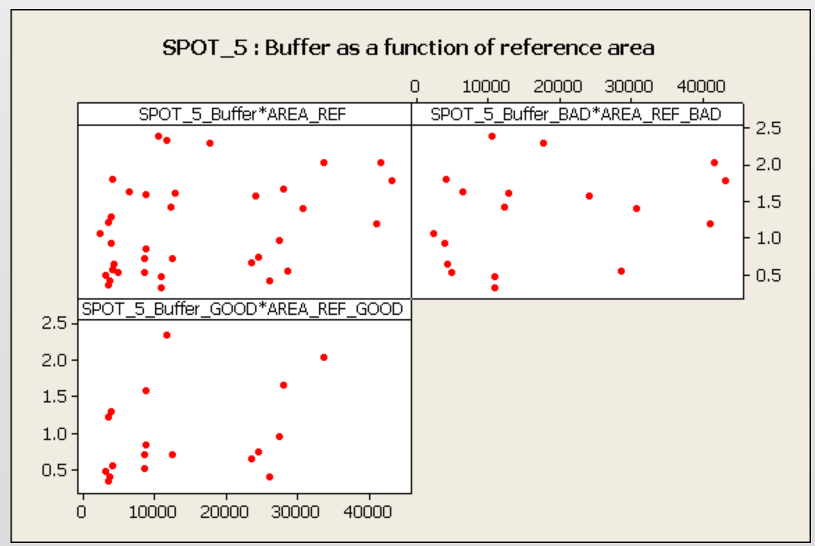
EROS

All	Buffer = 1.007 (0.704)
Good border Bad border	Buffer = 0.859 (0.387) Buffer = 1.155 (0.908)

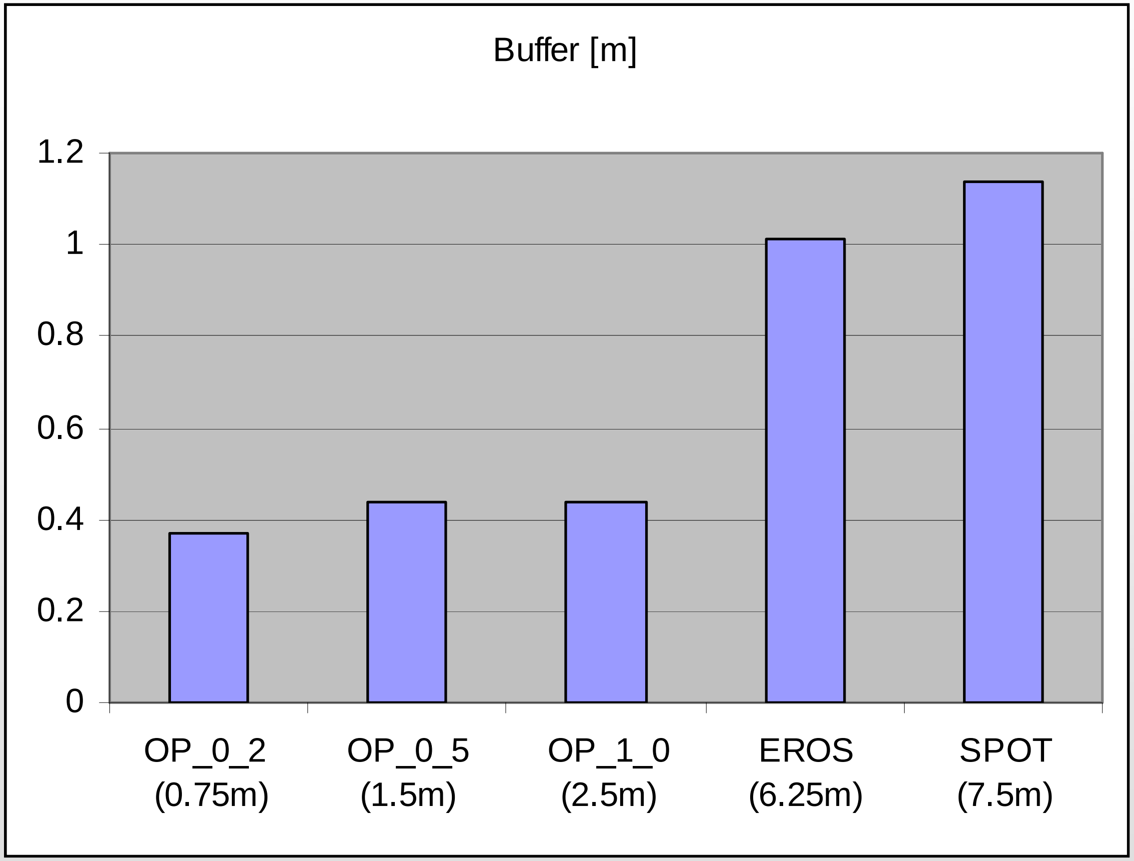
SPOT

All	Buffer = 1.142 (0.635)
Good border Bad border	Buffer = 0.972 (0.594) Buffer = 1.312 (0.645)



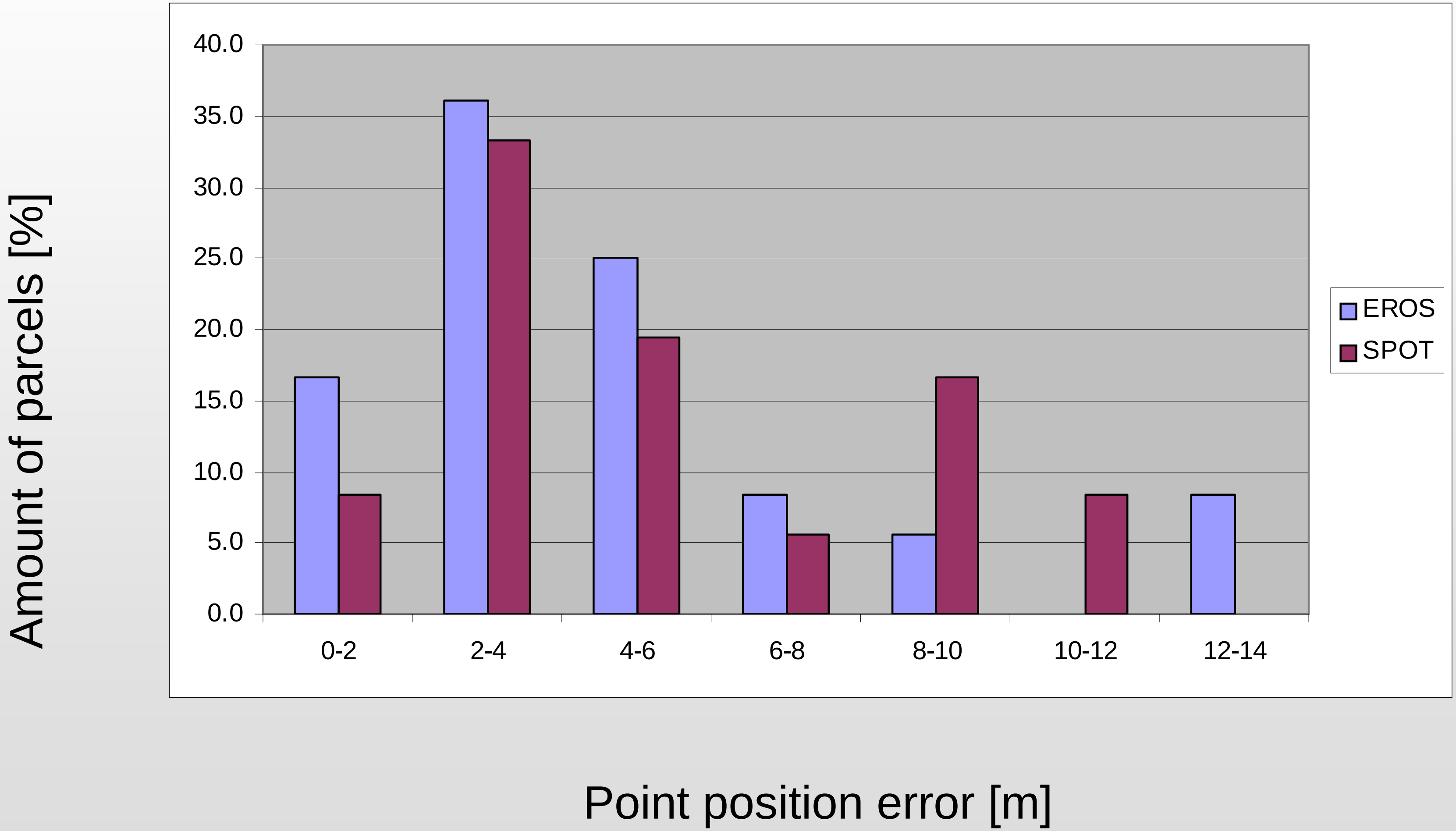


Buffer for all RS data

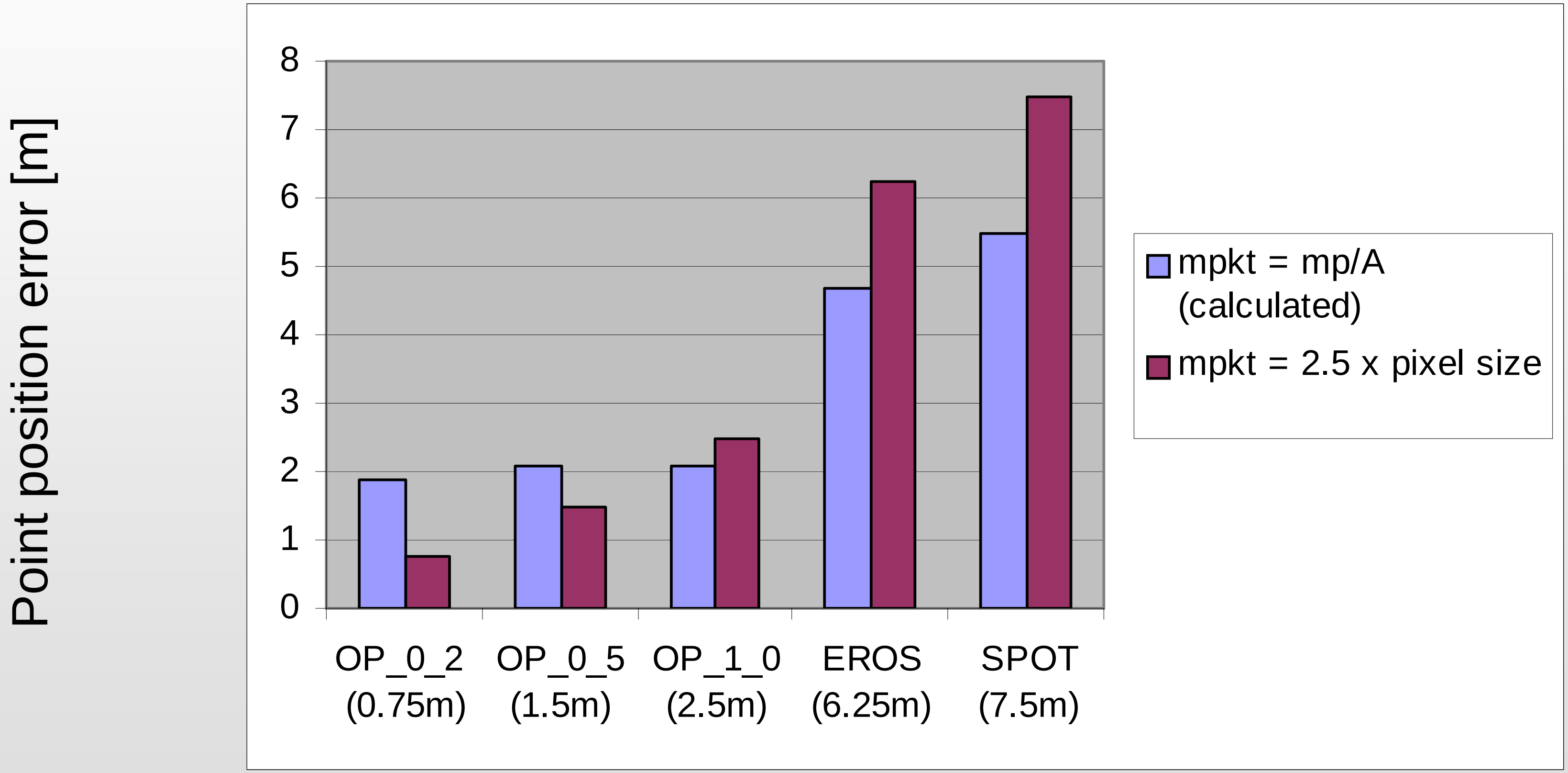


RMS

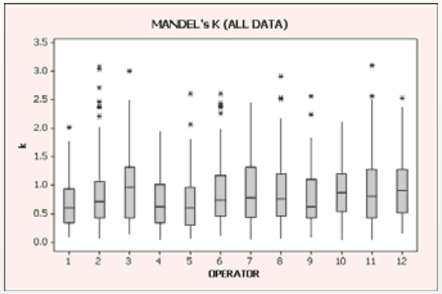
Point position error analysis

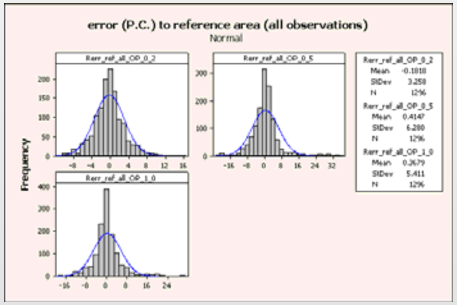


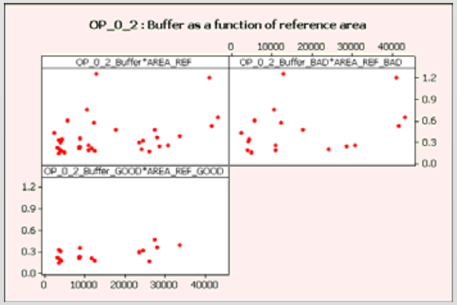
Point position error for all RS data

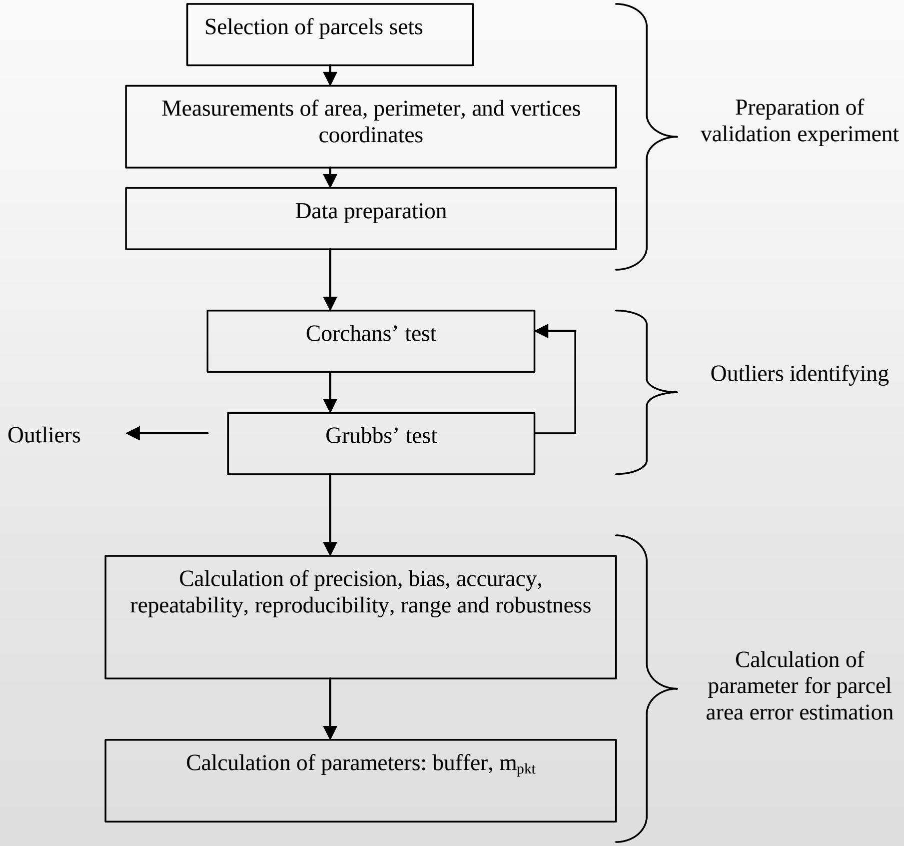


Validation method - proposed workflow









How many measurements

- *(Earlier recommendations were 16 to 60 measurements)*
- From Chp 9 of report:
- The numbers of parcels needed to reach a precision (half of the length of the 0.95 confidence interval) of 10 % of the mean values of the buffer are:
  - parcels = 10 rep. = 37 (370 observations)
  - parcels = 4 rep. = 67 (268 observations)
  - parcels = 1 rep. = 217 (217 observations)

- *Several approximations have been made to obtain these results and it could be useful to check them by using MC simulation.*

Parcel sets - amounts of operators repetitions

- two groups of six operators
- three groups of four operators
- four groups of three operators

So, the sequence has been repeated 972 times (36 parcels × 3 photos × 9 groups of operators)

The different groups of operators can be considered as replications

Mean values of the ratios (standard deviation/reference buffer)

Number of operators	OP_0_2	OP_0_5	OP_1_0
6	0.20	0.12	0.19
4	0.33	0.25	0.26
3	0.37	0.40	0.34

Parcel sets - amounts of operators repetitions

- *(Earlier recommendations were 16 to 60 measurements)*

- Main study: 36 parcels x 12 operators x 3 repetitions = 1296
- Middle variant: 36 parcels x 6 operators x 3 repetitions = 432
- Or 10 parcels x 12 operators x 3 repetitions = 360

December deadline for final proposal