European Commission

WikiCAP

Valid Method

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Contents

- JRC "Area measurement tool validation method"
    - A. Data collection
        - A. 1. For validation of GNSS devices
        - A.2. For validation of orthoimagery
    - B. Statistical analysis
    - C. Buffer tolerance estimation
    - D. Classification of the buffer width for a measurement tool
    - E. Report from validation
    - F. Documentation needed when the statistical analysis is to be made or validated by JRC
    - Tool already validated or certified
   - End of pages on the validation method

JRC "Area measurement tool validation method"

The validation method is designed to determine the intrinsic tool precision.

It should be set to limit as much as possible 'external' error factors (e.g. bad use of instrument, non-respect of parcel border …).

The validation test is made under 'artificial/controlled' conditions and has to be differentiated from a proficiency test that is performed under 'real operating' conditions. The result of the validation is strictly related to the whole set of method of measurement and not only to the device. Therefore, the certificate or the validation report remains valid as long as the operators respects the tested method conditions.

The quality of a measurement tool can be characterized by a number of parameters such as its bias, precision and accuracy. Assuming there is no bias, it can also be characterized by its reproducibility limit, which is the parameter used to determine the technical tolerance. The buffer validation method for both GNSS devices and ortho-imagery, is summarised in the following flow chart:

BUFFER TOLERANCE VALIDATION METHOD

GNSS measurements

At least:
- **6 parcels** with size, shape, type of borders typical for the future application during area control
- Parcels **borders will be marked by pegs** every 25-30 m
- **2(3) operators**
- **8(9) sets**, each set with **4 repetitions** (2 clockwise, 2 anticlockwise), 4(3) sets/operator
- Different time a day (2-3 days)
- Reference areas of parcels should be measured with accurate tools (RTK or post processing carrier phase GNSS devices, total stations, etc.)

Minimum 32 measurements for each parcel

Orthoimagery

At least:
- **30 parcels** with size, shape, type of borders typical for the future application during area control
- Parcels borders area natural, **largely indicated** as in the figure, **selected as LPIS** if possible
- **6 operators**
- **6 sets**, each set with **4 repetitions**
- Each repetition measured in different time a day
- Reference areas of parcels should be taken from LPIS

Minimum 24 measurements for each parcel

Statistical analysis

Outliers detection

Calculation in the area value (m^2)
- Repeatability standard deviation ISO 5725-2: formula (20)
- Reproducibility standard deviation ISO 5725-2: formula (24)

Reproducibility limit in buffer value (m) = 2.8 * reproducibility standard deviation/parcel perimeter

A. Data collection

It is highly recommended to contact JRC at the earliest stage of the exercise to check that the whole protocol of data acquisition (i.e. number and choice of parcels, number of repeated measurements, number of sets…) is in line with the present guidance.

A. 1. For validation of GNSS devices

The test covers the whole set of: hardware, software, settings and method.

The test parcels should have unambiguous borders to ensure that all measurements cover the same object. For instance, the borders could be marked with wooden sticks with a density of at least 1 peg per 25m. Objects should be of variable sizes (at least covering the range over which the GNSS should be working, for instance between 0.4ha and 4ha) and shapes (at least one elongated parcel should be included).

Number of fields

The more fields chosen for the test, the more reliable the assessment: more data collected give more points on the receiver characteristic curve. It is recommended to take at least 6 fields with sizes spread along the typical size range of the country.

Shape

The shape of the fields should vary from very simple shapes (e.g. rectangular) to some irregular shapes with high perimeter to area ratio.

Obstructions of the horizon

Validation test results conducted showed, a high impact of horizon obstruction on the buffer, e.g. parcels with trees to the south often show a significantly higher R-limit than parcels without tree obstruction. Selecting most test parcels in an open horizon environment is likely to result in a (low) buffer, which may not be appropriate to the usual conditions in which the device is used. Terrain characteristic and the type of cultivation is an important issue due to possible disturbances of the satellite signal. In mountainous areas or on fields (partly) bordered by trees, the "visibility" of the satellites may be limited, which may result in higher measurement errors. If parcels with partially obstructed borders are common in the region or country, such parcels should be included in the test to reflect the average conditions of measurement in the region/country.
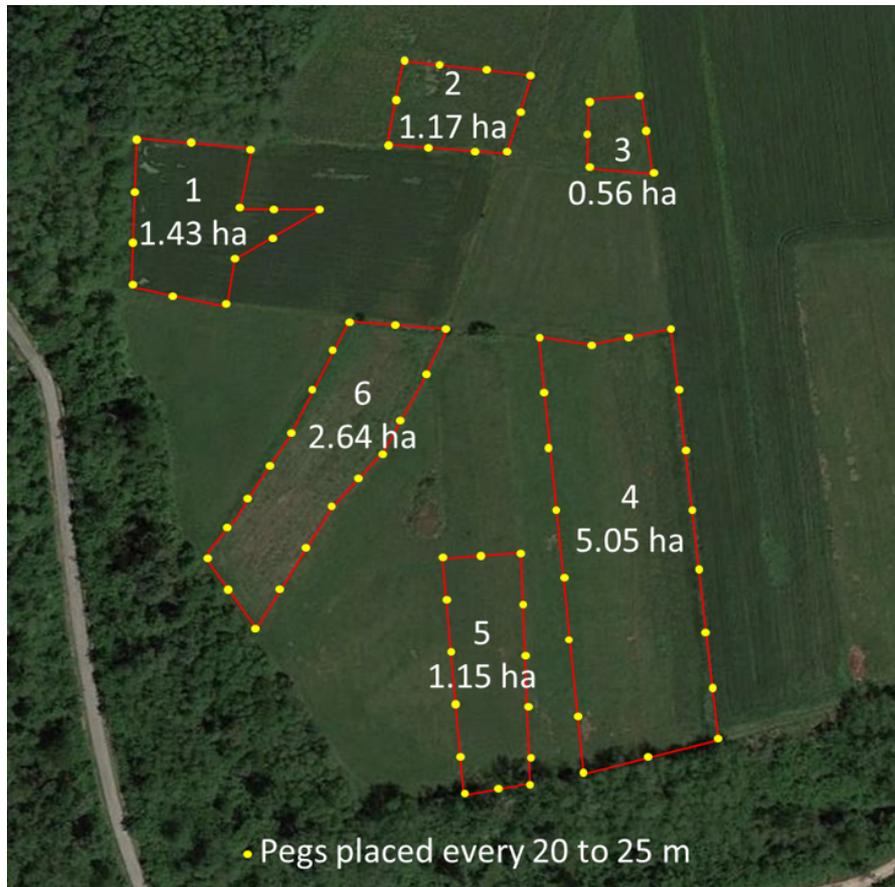
Example of validation test fields set

Borders of the test field

The test fields should have easily accessible borders (no stones, bushes to cross, marshy spots etc.) to allow operators walking without difficulty around them.

Reference value

Standard deviation of measurement repetitions should be estimated **against a reference area** of the considered parcel. The reference area of the test parcels should be established with a surveying tools or GNSS RTK measurements. It can also be taken from a LPIS reference area if a reference shape corresponds to it.

Repetitions

The GNSS constellation should be considered as relatively stable while collecting data on each field. In other words, the time needed to measure one field four times is short enough (normally 10 to 30 minutes, depending on the perimeter of the field) to consider the satellite constellation as stable. The four measurements taken in a short period of time, by the same operator, will allow to derive the repeatability variance of the area measurements.

Runs (sets) of measurements

The revisit time for the GNSS satellite constellation is equal to ~12h. In order to make measurements under different constellations (i.e. different number of satellites and different satellites in view), the different runs should start at different times of the day. At least 1.5 - 2 hours should be left between two successive runs to consider that the satellite constellations have changed. The variance between runs of measurements will be used to derive the reproducibility variance of the area measurements.

DAY 1

DAY 2

Parcel	Approximate perimeter	Estimated time to measure the **4 repetitions** (1 set = CW, ACW, CW, ACW) for each field
1	500-600 m	± 30 min
2	500-600 m	± 30 min
3	650-700 m	± 40 min
4	± 200 m	± 15 min
5	± 250 m	± 20 min
6	± 400 m	± 30 min
Total for one set		2:30h - 3:00h
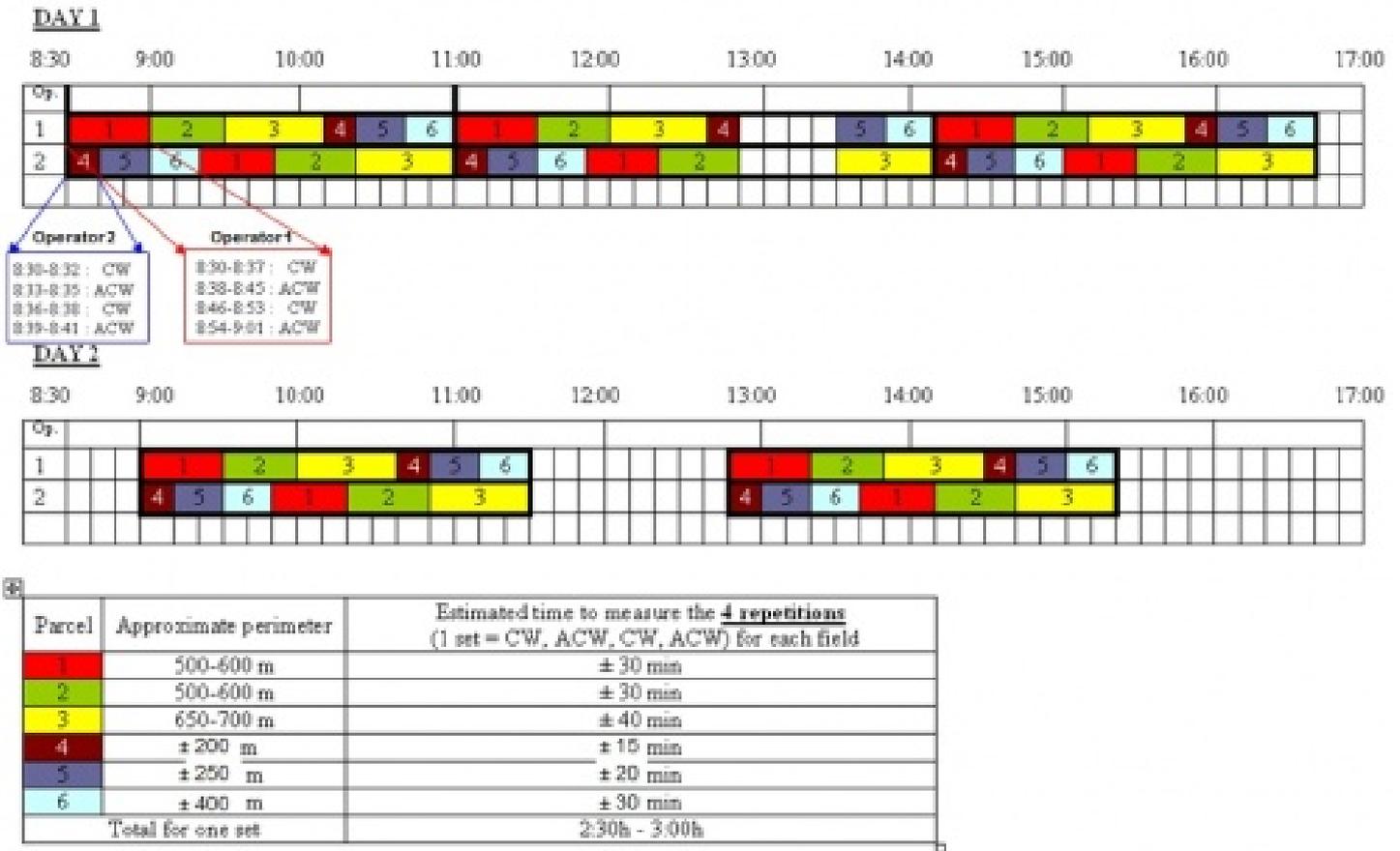
Example of organization of field measurements for 6 parcels with 2 operators

Settings

The test must be performed with exactly the same settings that will be used during OTS check work (max DOP, S/N ratio, logging interval).

Method

In best practice, it is recommended to perform most of the measurements in continuous mode. However, in real field controls there are situations where the GNSS device has to be used in continuous AND vertex measurement modes (so-called stop-and-go method).

Therefore, so the device must be validated for both modes (**continuous** logging and log of **vertices**).

For area measurement done using vertices, the distance between two successive vertices should **not be greater than 25m**. This is to "simulate" the natural landscape measurement conditions, where the borders are rarely straight and data are logged more frequently than when measuring rectangles. However, in case of very elongated straight parcels (i.e. more than 400, 500 meters long) the distance between two successive vertices can be extended to 100, 150 meters (but marked clearly with a density of at least one marker/peg for 20-25m). On each of the vertices, the operator should remain several seconds to get several records per point. In continuous mode also, the operator should remain some seconds at each corner. Drastic change of direction of the parcel border.

Avoiding systematic errors

Operators should not disturb each other while measuring so if possible one operator should measure one parcel at one time. In order to avoid potential systematic errors related to left/right handed operators,

The direction of walking should be both in clockwise and anticlockwise.

e.g.: for all the runs: 1st repetition – always clockwise, 2nd repetitions always anticlockwise, 3rd – clockwise, 4th – anticlockwise.

A.2. For validation of orthoimagery

On orthoimagery, repetitions of measurement are less time consuming than field measurement, thus the minimum number of parcels and repetitions could be increased to **at least 30 parcels**. In order to ease the work, it is advised to select parcels corresponding to LPIS reference parcels (reference area already available). Otherwise, it will be necessary to measure the reference area on field using a surveying tools or GNSS RTK measurements. Area measurements of these parcels performed by **at least 6 operators** (for proper statistical analysis) Each operator performing **at least 4 measurements** (repetitions) of each parcel (for proper statistical analysis) For what concerns the parcels' selection:

- Parcels selected should be a representative sample of the control area zone (strongly related to the parcel structure)
- Parcel sizes should cover the range observed in the control area

> S: small
> M: medium
> L: large

- Parcel shapes should vary

> SF1: compact
> SF2: elongated
> SF3: very elongated

- Some parcels should be selected with easily identifiable borders as to avoid interpretation problems and lead to some parcels rejections later on during the analysis

Remarks concerning choice of the parcel size and shape ranges

Before parcel set definition, (size and shape) statistical analysis of the parcel structure on the area to be controlled should be performed. In the first step parcel areas are sorted and 5% of outlying values are discarded (percentiles: 97.5% and 2.5%). In the next step the remaining range is divided by 3 equal parts (small, medium and large size). Parcel area and perimeter allow for Shape Factor calculation ($SF = (perimeter/4)^2/area$). The same procedure should be performed for SF (compact, elongated and very elongated parcels).

Example of parcel set (30 parcels):

- good border: 15 parcels

> S and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
> M and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
> L and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels

- "fuzzy" border: 15 parcels

> S and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
> M and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
> L and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels

Remarks concerning choice of scale for digitisation

> Considering the pixel size of imagery to validate (i.e. <= 0.5m), the scale for digitization should be around 1/1.000. Nevertheless, the scale should not be fixed to 1/1.000 and should be adapted on a parcel per parcel basis.

Example of parcel border

Some examples are provided hereafter in order to illustrate the concepts of 'easy border', 'fuzzy border' and 'borders leading to interpretation problems'.

Examples of 'easy' and 'fuzzy' borders that should be part of the parcels sample

Examples of parcels with limits difficult to delineate (photo interpret) and that should **not be part** of the selected parcels sample.

Precise, commons and detailed instructions (the same as used for creation of reference parcels – LPIS if parcel based LPIS available) have to be given to the photo interpreters.

For field parcels, pegs are provided to clearly identify parcel borders. For ortho-images it is not possible to provide the equivalent of pegs otherwise there will be a risk that photo interpreters digitize these vertices/lines not doing interpretation of the image.

Therefore, as guide for interpretation, a shape surrounding the parcel to be measured, has to be created in advance for all parcels in the sample, and shown on the screen during the measurement.

Red : LPIS boundaries. To not be shown to the operators !!! To be used only as reference area.

Shape to help the operators to identify the right parcel to be digitalized

Precise, commons and **detailed** instructions for operators (exactly the same as used for creation of reference parcels – LPIS)

Wrong digitalization result not following the appropriated rules

Good digitalization result following the appropriated rules
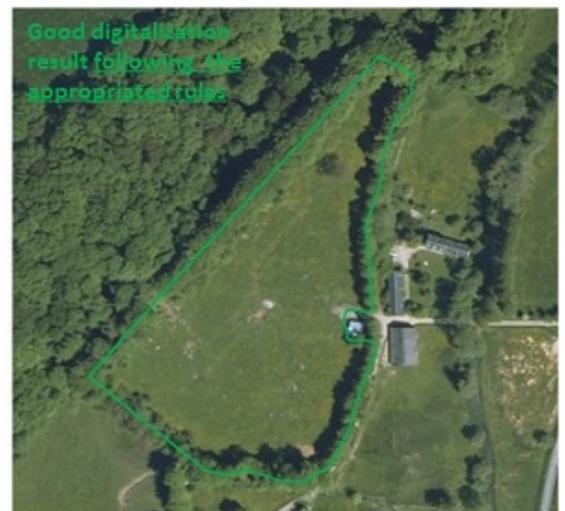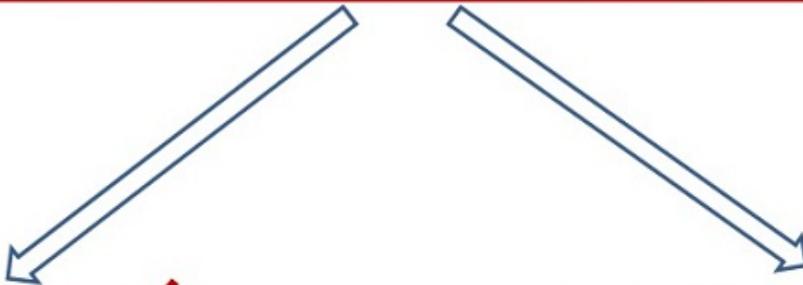
As for the GNSS validation protocol, the reference area and perimeter of the test parcels should be established (from LPIS if available or performing field measurement using surveying tools or GNSS RTK measurements).

B. Statistical analysis

Collected data

The results of the area measurements performed in validation process should be collected like in Table A of ISO 5725. In each cell, there is measured parcel area (in this case in square meters). Each 4 repetitions define one set, or used in ISO 5725 one laboratory, or sometimes called one run. So one operator delivers 3 sets (in GNSS validation, see diagram above and table below). Level in ISO 5725 means in our validation procedure - parcel (6 parcels: A, B, C, D, E and F - 6 levels).

Table A

Operator - i	Lab - L	Repetition k	Observation results (9 sets per parcel, 4 repetitions per set)					
			Level - j parcel					
			A	B	C	D	E	F
			y_i					
set, run laboratory	1	1	5386	2981	14123	4372	9647	1877
		2	5319	3020	14135	4362	10288	2308
		3	5344	2944	14136	4380	10028	1890
		4	5295	3021	14123	4399	10223	2168
1	2	1	5341	2968	14122	4321	9277	1936
		2	5366	3133	14130	4423	10333	2282
		3	5377	2971	14102	4379	9541	1850
		4	5341	3036	14104	4390	10291	2245
	3	1	5367	2972	14129	4362	9913	1875
		2	5362	2979	14128	4399	10321	2337
		3	5366	2952	14135	4335	10027	1979
		4	5371	2979	14120	4017	10374	2264
2	4	5	5327	3040	14137	4408	9683	1824
		6	5358	3064	14151	4384	10539	2242
		7	5322	3054	14131	4389	9786	1847
		8	5352	3042	14186	4316	10460	2253
	5	5	5398	3032	14135	4367	9815	1890
		6	5382	2908	14134	4342	10416	2287
		7	5328	3020	14112	4422	9904	1890
		8	5367	3023	14148	4420	10299	2220
	6	5	5350	3022	14106	4356	9876	1859
		6	5386	3013	14103	4392	10303	2278
		7	5340	2661	14103	4363	9975	1890
		8	5342	3044	14105	4359	10189	2281
3	7	9	5394	2947	14073	4302	10044	1971
		10	5345	3014	14060	4350	10165	2191
		11	5341	2856	14088	4372	10077	1955
		12	5381	3064	14054	5180	10242	2192
	8	9	5337	3020	14125	4428	9940	1962
		10	5354	2966	14126	4383	10221	2100
		11	5372	3038	14118	4405	10063	2024
		12	5393	2952	14139	4396	10188	2153
	9	9	5365	3018	14110	4467	9972	1923
		10	5361	2956	14115	4378	10234	2460
		11	5390	3025	14180	4457	10079	1875
		12	5369	3039	14112	4399	10355	2460

Basic statistics

Next for each parcel mean area and standard deviation for each set is calculated (Table B and C in ISO 5725-2).

Table B - Recommended form for the collation of the means

A	B	C	D	E	F
5335,9	2991,7	14129,4	4378,1	10046,5	2060,8
5356,5	3027,0	14114,4	4378,3	9860,5	2078,3
5366,3	2970,6	14127,8	4278,5	10158,8	2113,8
5339,4	3049,9	14151,0	4374,0	10117,0	2041,5
5368,9	2995,5	14132,2	4388,0	10108,5	2071,8
5354,5	2935,0	14104,3	4367,6	10085,8	2077,0
5365,3	2970,3	14068,7	4551,1	10132,0	2077,3
5364,0	2994,2	14127,2	4403,0	10103,0	2059,8
5371,2	3009,7	14129,3	4425,4	10160,0	2179,5

Table C - Recommended form for the standard deviation

A	B	C	D	E	F
18,27	77,29	13,93	42,38	532,65	217,30
3,80	12,80	6,04	176,14	223,91	221,79
17,82	11,17	24,68	40,05	444,84	238,10
29,84	58,53	15,03	39,81	293,72	211,64
21,62	182,91	1,50	16,53	195,04	234,17
26,43	90,13	15,13	420,42	89,36	132,09
23,86	41,70	8,76	18,87	128,22	83,96
12,92	36,68	33,90	43,58	168,73	324,49

One should make sure to avoid rounding the values of the mean and standard deviation statistics. Slight differences can propagate and create numerical issues (e.g. negative value where a positive value is expected).

Outliers detection

The statistical parameters concerning the buffer tolerance value should be calculated only for the dataset free of outliers. Therefore the collected data need to be tested for outliers see flowchart below. Cohran's test is described in chapter 7.3.3 and Grubss' test in chapter 7.3.4 of ISO 5725-2.

- **Cochran's test (in blue)** checks variation of standard deviation between classes.
- **Grubbs' test for single observation (in dashed green)** checks variation of observed value in class (standard deviation is calculated within class).
- **Grubb's test for 1 outlying mean (in yellow)** or for 2 outlying means (in dashed orange) checks variation of means between classes, standard deviation is calculated between classes.
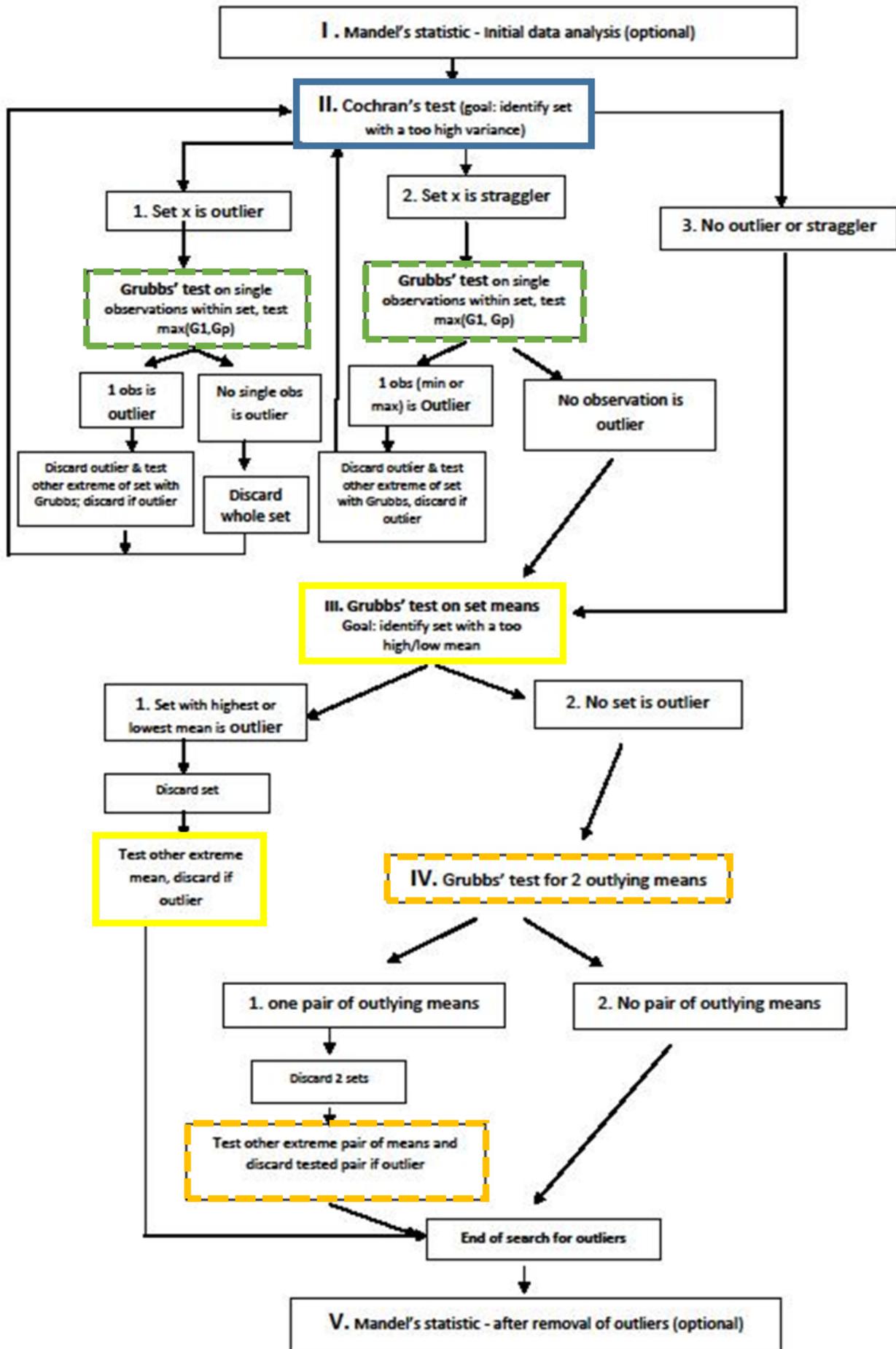
Cochran's test statistic C

$$C = \frac{s^2_{max}}{\sum\limits_{i=1}^{p} s_i^2}$$

s_i - standard deviation for i set

s_{max} — the highest standard deviation of the all sets

Grubbs' test statistic G

$$G_p = (x_p - \bar{x})/s$$

where

$$\bar{x} = \frac{1}{p}\sum\limits_{i=1}^{p} x_i$$

and

$$s = \sqrt{\frac{1}{p-1}\sum\limits_{i=1}^{p}(x_i - \bar{x})^2}$$

p - number of sets

x_i — mean area in i set

During the outliers' detection, follow the flowchart above and perform the tests according ISO 5725-2.

Two of the four tests are always performed at least once (in plain color rectangles in the flowchart): the Cochran's and the Grubbs' test for 1 outlying mean.

The remaining two tests are performed only in specific conditions (see the dashed rectangles in the flowchart steps II.1, II.2, III.2 and IV.1).

After the outliers removing tables: A, B and C are modified. It is recommended to put the reason of outliers discarding in table A. Single observations or all sets can be removed. In such a case, the number of sets and the number of observations must be updated for detecting the potential remaining outliers (e.g. the critical value for the Grubb's test on 1 outlying mean is 1,973 for 6 sets and becomes 1,764 for 5 sets). For the details, please refer to Tables 4 and 5 of ISO 5725-2.

    - Calculation of repeatability and reproducibility

After outliers detection the uncertainty of parcel area measurements is estimated.

ISO 5725-1 sets the general definitions for:

    - **Repeatability standard deviation**: the standard deviation of test results obtained under repeatability conditions.

    - **Repeatability conditions**: conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time.

    - **Reproducibility standard deviation:** the standard deviation of test results obtained under reproducibility conditions.

    - **Reproducibility conditions:** conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment.

    - If the computed between-laboratory standard deviation sL_j^2 is negative, it must be manually set to 0. In such case, $sr_j^2 = sR_j^2$.

$$s_{rj}^2 = \frac{\sum\limits_{i=1}^{p}(n_{ij}-1)s_{ij}^2}{\sum\limits_{i=1}^{p}(n_{ij}-1)} \qquad\qquad s_{Rj}^2 = s_{rj}^2 + s_{Lj}^2$$

s_{rj} – standard deviation of repeatability

j – level (parcel)

i – set

n_{ij} – number of repetitions for set i and parcel j

s_{ij} – standard deviation for set i and parcel j

s_{Rj} – standard deviation of reproducibility

s_{rj} – standard deviation of repeatability

s_{Lj} - between-laboratory standard deviation (ISO 5725 – 2 chapter: 7.4.5.2)

j – level (parcel)

	A	B	C	D	E	F
srj^2	552,8492	2583,9474	164,8867	1124,1431	63545,2292	39031,0833
sLj^2	24,5992	57,3501	504,1034	282,3688	-14463,8653	-9575,2738
sRj^2	577,4484	2641,2975	668,9901	1406,5119	63545,2292	39031,0833

In the example, the computed between-laboratory standard deviation sLj^2 are negative for the parcels E and F. One can see that in that case srj^2=sRj^2.

- Verification of bias and influence of pooling factors.

According the inter-laboratory tests performed in the past and during ongoing projects, the significant, repeatable and rigid influence of parcel border quality on the value of reproducibility was observed. Any other factors should not influence the validation results. However, we observed in some cases the bias, influence of the operator, walking direction, measurements day, parcel area and size etc. But generally we expect no bias and no influence of any factors presented in the table below. Therefore, we recommend performing bias test (basing on the formulas in IS0 5725-2 chapter 7.4.5, ISO 5275-4 chapter 4.7.2 or T-Student test). Influence of the other factors is recommended to verifying using ANOVA analysis.

No significant, repeatable, rigid influence	
GNSS	Orthoimagery
Parcel size	
Parcel shape	
No – bias (difference between mean measured parcel area and reference area)	
Skilled/unskilled observer (however training is strongly recommended)	
Direction of walking	
Day, time (satellite constellation)	

Significant influence	
GNSS	Orthoimagery
Mask (i.e. trees on the parcel border)	Quality of parcel border (good and bad)

C. Buffer tolerance estimation

Repeatability and reproducibility standard deviations are for each parcels in square meters. Reproducibility limit in area values [m^2] depends on parcels so for the standardization it should be divided by reference perimeter to obtain reproducibility limit in buffer values [m].

According ISO 5725-6 chapter: 4.1.4: when examining two single test results obtained under reproducibility conditions, the comparison shall be made with the reproducibility limit (in our case: buffer limit): RL=2,8 (sRj in buffer).

	A	B	C	D	E	F
sRj^2 [m^4]	577,4484	2641,2975	668,9901	1406,5119	63545,2292	39031,0833
sRj [m^2]	24,0302	51,3936	25,8648	37,5035	252,0818	197,5629
perimeter [m]	296,38	391,59	468,27	269,00	608,13	400,00
sRj in buffer = sRj/perimeter [m]	0,0811	0,1312	0,0552	0,1394	0,4145	0,4939
Buffer limit = 2,8 sRj in buffer	0,2270	0,3675	0,1547	0,3904	1,1607	1,3829

D. Classification of the buffer width for a measurement tool

Reproducibility limit calculated in validation process allows classifying the area measurement method to the one of the following classes:

- (1) "1.0m" for RL inside (0.75m, 1.0m];
- (2) "0.75m" for RL inside (0.50m, 0.75m];
- (3) "0.50m" for RL below 0.50m.

Mean value of repeatability in buffer for our example: 0,61 m so the validated method is classified into class (2): buffer limit taken to the control should be: 0,75 m.

E. Report from validation

Report from validation should include following information:

- (1) Validated equipment: type of GNSS receiver with software (type and version), serial numbers of each entity, metadata about orthoimagery (type, resolution, uncertainty from quality control etc.);

- (2) In the case of GNSS receivers:

> device settings (elevation mask, max DOP, etc.);

o details about the validated method: vertex + number of logs per vertex / continuous + logging interval;

> use of differential correction and type of correction;
> measurements with or without external antenna.

- (3) reference parcels areas and perimeters, details about the measurements method applied for reference measurement;
- (4) design of parcels set;
- (5) table A with some explanation if needed (notice about the not normal procedure, applied equipment if changed or shared between operators, gross error etc.);
- (6) basic statistic before outliers discarding: table B and C;
- (7) results of outliers testing: table A with the removed single observations and/or all sets;
- (8) repeatability and reproducibility standard deviation in [m^2] and in buffer values [m];
- (9) results of bias analysis and ANOVA analysis;
- (10) buffer limit and class of the validated method;
- (11) Test data.

An example of xls file containing the collected data from an area measurement validation test can be found on WikiCAP Template (https://marswiki.jrc.ec.europa.eu/wikicap/images/f/fe/ISO_5725-2_template.zip).

F. Documentation needed when the statistical analysis is to be made or validated by JRC

1. In case a MS decides to entrust JRC with the statistical analysis after data collection, the following information should be sent to JRC for final analysis:

> - Report from validation of the test carried out by MS (points: 1-5). Last four points (6, 7, 8 and 9) will be prepared by JRC (outliers detection, repeatability and reproducibility standard deviation calculation, buffer limit determination and result of method classification).
> - Detailed description of validation procedure (protocol) should be delivered.
> - Raw measurements data
>
>> In the case of GNSS - a copy of the measurement protocol indicating parcel id, date and time, set, repetition, operator, direction of measurement, area measured, perimeter measured.
>> In the case of orthoimagery validation all vector files should be delivered.

A technical report and the data will document the whole validation process; they will help JRC to evaluate and analyze the data as well as to draw conclusions on the tolerance to be used with that device and measurement method. The final statement on the performance of the system will be prepared by the JRC on the basis of the test results. 2. In case a MS decides to perform the validation tests and the statistical analysis by itself a technical report, data and the sheets with the statistical analysis (templates to be asked to JRC) should be sent to the JRC for validation, final assessment and publication of the results on the JRC web page.

Tool already validated or certified

NOTA BENE: the list of tools validated so far can be found under that LINK (https://marswiki.jrc.ec.europa.eu/wikicap/index.php/GNSS_valid).

End of pages on the validation method

Go back to the Navigation page OTSC

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