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Validation of GNSS receivers: step by step

Introduction

Since beginning of 2008 Members States are obliged by the article 30(1) of Commission Regulation (EC) No 796/2004 to determine the areas of agricultural *"by any means proven to assure measurement of quality at least equivalent to that required by applicable technical standard, as drawn up at Community level."* That means, that a proof of quality of the tools/methods used for on-the-spot checks should be present.

This poster is presenting nine steps that could be taken in order to fulfill that requirement. Proposed approach and workflow is based on ISO 5725 norm and has been developed in the course of several studies undertaken by universities and the JRC.

Please note, that the JRC is available for the Member States to support steps 7 and 8 of the validation process.

1. Design test site

Test site should be representative for operational environment (region/country) of the tool and include minimum 5 fields of variable:

- size,
- shape,
- border obstructions.

Example:

- 6 fields of sizes between 0.2ha and 1.5ha,
- 3 fields have clear horizon (D,E,F),
- 3 fields with forest on a border (A,B,C),
- 2 fields of the same size and shape but differe border obstructions (C,D),
- 1 very elongated field (E),
- 1 field with irregular shape (B)

2. Mark the borders of fie

Make sure that the borders of fields are easily recognizable and comfortable for walking.

3. Reference area

Measure the area of the field with high precision instrument (RTK, surveying instruments). These reference areas are needed to estimate the bias (point 7.3).

4. How many measurements?

A **repetition** is a single measurement of a field. Repetitions taken in short intervals of time compose a **set of measurements** (runs).

It is recommended to collect at least 8 sets of measurements consisting of 4 repetitions per field.

5. Schedule your measurements

We assume that the GNSS satellite constellation is stable between successive repetitions. It should be however variable for successive sets of measurements.

Conclusion: per each field collect repetitions as fast as possible but keep a time-distance between successive sets of measurements of the field.

Example: Test designed for 3 operators on 6 fields. Schedule of collection of 9 sets of measurements (3 per operator), consisting of 4 repetitions, over 2 days.

In each run operators should measure as follows:

Operator 1	Operator 2	Operator 3
A (cw, acw, cw, acw)	B (cw, acw, cw, acw)	C (cw, acw, cw, acw)
B (cw, acw, cw, acw)	C (cw, acw, cw, acw)	D (cw, acw, cw, acw)
C (cw, acw, cw, acw)	D (cw, acw, cw, acw)	E (cw, acw, cw, acw)
D (cw, acw, cw, acw)	E (cw, acw, cw, acw)	F (cw, acw, cw, acw)
E (cw, acw, cw, acw)	F (cw, acw, cw, acw)	A (cw, acw, cw, acw)
F (cw, acw, cw, acw)	A (cw, acw, cw, acw)	B (cw, acw, cw, acw)

cw – clockwise
acw – anti-clockwise

Schedule of runs over 2 days:

	Day 1	Day 2
Run 1	8:00-12:00	-
Run 2	13:00-17:00	-
Run 3	-	10:00-14:00

6. Collect the data

Measuring in both clockwise and anti-clockwise direction will help to identify potential systematic errors related to left/right handed operators.

Take notes of at least:

- field ID,
- operator ID,
- time of measurement,
- area,
- perimeter,
- direction: cw, acw
- any extraordinary behavior of the device.

Use all the settings of receiver that are normally used during control !

7. Statistical processing

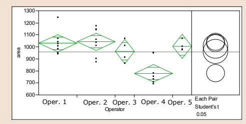
7.1 Detect outliers

Grubb's and Cochran's tests for outliers are recommended in ISO 5725 to identify strugglers and outliers within data sets and between them. Any other statistical tests capable to do that are acceptable.

7.2 Analyze impact of different factors (ANOVA)

In order to verify dependence of the errors on different factors an analysis of variance of the measurements should be performed. Impact of (at least) the following factors should be analyzed:

- field,
- operator,
- set of measurements,
- direction: cw, acw,
- size of field,
- shape of field.



Example: Operator 4 obtained significantly different results on one of the fields than the others.

7.3 Check absence of bias in results

By comparison between the grand mean of the measurements of a field and its reference area verify existence of the bias and its significance (Student's t-test).

7.4 Compute reproducibility standard deviation: s_R

For each field compute the following parameters:

$$T_1 = \sum n_i \bar{y}_i \qquad T_2 = \sum n_i (\bar{y}_i)^2 \qquad T_3 = \sum n_i \qquad T_4 = \sum n_i^2 \qquad T_5 = \sum (n_i - 1) s_i^2$$

Compute the repeatability variance (within the sets of measurements) s_r^2 and variance between sets of measurements s_L^2:

$$s_r^2 = \frac{T_5}{T_3 - p} \qquad s_L^2 = \left[\frac{T_2 T_3 - T_1^2}{T_3(p-1)} - s_r^2\right]\left[\frac{T_3(p-1)}{T_3^2 - T_4}\right]$$

Calculate the reproducibility standard deviation for a field:

$$s_R = \sqrt{s_L^2 + s_r^2}$$

Where:
n_i – number of repetitions in *i* set of measurements,
$\bar{y}_i$ – mean of the *i* set of measurements,
s_i – standard deviation of repetitions in *i* set of meas
p – number of sets of measurements

7.5 Compute reproducibility l

For each field compute the reproducibility limit

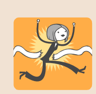
$$R = 2.8 \cdot s_R$$

An arithmetic mean of the reproducibility limits of all the fields will be your final value of reproducibility limit of your tool/method in area measurements.

8. Derive the technical tolerance to be used

The technical tolerance to be used with the tested tool should be derived as follows:

- 0.50m for R ≤ 0.50m
- 0.75m for R inside (0.50m, 0.75m]
- 1m for R inside (0.75m, 1.00m]
- 1.25m for R inside (1.00m, 1.25m]
- 1.5m for R inside (1.25m, 1.50m]



9. Document all the process

In your report describe the test site and the workflow. Present the results of the statistical processing, rejected outliers and the final values of reproducibility limits.

For more details, please refer to: http://marswiki.jrc.ec.europa.eu/wikicap/index.php/GPS_equipment_-_validation

Remember! you test: hardware + software + settings + method