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European Commission

JRC TECHNICAL REPORTS

TECHNICAL GUIDANCE

FOR ON-THE-SPOT CHECKS (OTSC) AND AREA MEASUREMENT ACCORDING TO ART. 24, 25, 26, 27, 30, 31, 34, 35, 36, 37, 38, 39, 40, 41 OF REGULATION (EU) NO 809/2014 AS AMENDED BY REGULATION (EU) 2015/2333

Common Technical Specifications for the 2018 campaign of On-The-Spot Checks

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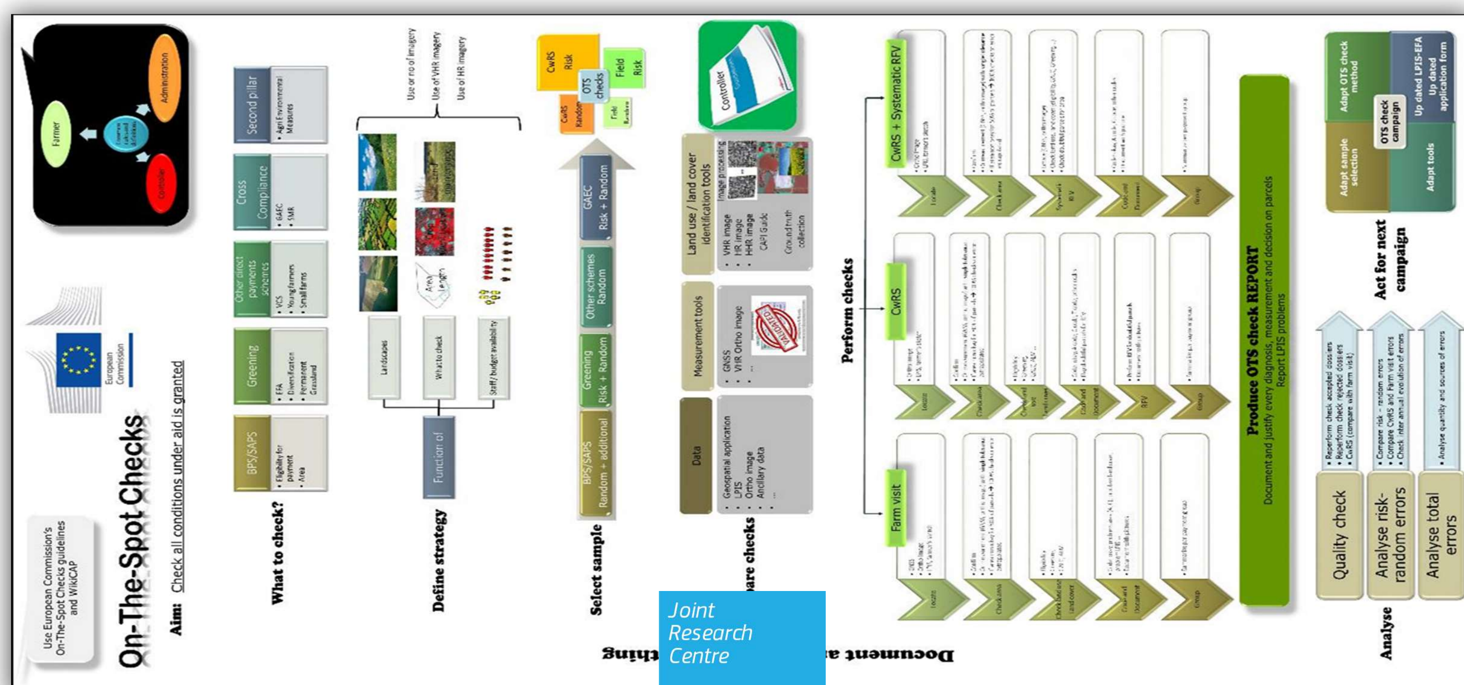

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Pre-amble

This document, which has been prepared by the European Commission (Joint Research Centre, JRC) in close collaboration with DG AGRI, describes the Commission technical guidelines for the 2018 campaign of the On-The-Spot Checks (OTSC). Member States may use these guidelines as Common Technical Specifications of the Invitation To Tender (ITT) published by Member States requiring an external remote sensing contractor. It complements the guidance document for OTSC and area measurement: *DS/CDP/2018/10*.

The document aims to describe the technical tasks that the Administrations of the Member States are responsible for and for which some parts may be entrusted to contractors. For the sake of completeness, however, the technical context of the work requires some descriptions of the role and responsibilities of both the Administration and the Commission. Some of the technical details may seem exhaustive, but are included to allow Member State Administrations, and possible contractors, the best possible chance to estimate the expected workloads. Furthermore, as a common document, it has to be inclusive of all the possible choices, options and alternatives that are used in the Member States for their On-The-Spot Checks.

This document provides technical guidance on how to perform On-The-Spot Checks in general. However, since the majority of the European Union Member States is using Remote Sensing to control at least a part of the subsidies for the agricultural areas funded by the EAGF and EAFRD, most of the information provided concern the implementation of the so-called "Control with Remote Sensing" (CwRS).

This document has to be complemented by a separate compulsory "**National Addendum**", which describes the choices and alternatives applicable in the respective Member State. The information given in this "National Addendum" must be taken into account in the bidders' reply to ITT. This is all the more necessary as different schemes coexist in the EU 28 which will be applied with different models and variants. Since these Common Technical Specifications do not take into account all particular situations in the different Member States, derogations from particular rules indicated in this document should be introduced in the National Addendum.

The information in this document is up-to-date with the existing EU regulations that are applicable at the time of writing. It is the MS Administrations and the contractors' responsibility to be aware of other general or specific regulations applicable in their respective Member States.

Technical Recommendations regarding the different phases of the work are also available on the WikiCAP website[1]. It is suggested also to refer to the technical specifications regarding the VHR and HR imagery used for the CWRS [2]

The role of the Commission in a possible procurement procedure for a contractor to perform OTSC work, is strictly restricted to the technical support required to compile the ITT document. The selection, award and follow-up of any contract following from this open procedure is the sole responsibility of the awarding authority in the respective Member States.

While the Commission has attempted to make the information contained in these common technical specifications as accurate as possible, it does not warrant the accuracy of the information contained or embodied in the document. The Commission does not warrant or make any representations as to the accuracy of the information contained in the National Addenda produced by respective Member States. Contracts awarded are the sole responsibility of the awarding Administrations in the respective Member States.

[1] https://marswiki.jrc.ec.europa.eu/wikicap/index.php/Main_Page

[2] https://g4cap.jrc.ec.europa.eu/g4cap/Default.aspx?tabid=172

LIST OF ACRONYMS USED AND TERMINOLOGY FOR THE PURPOSE OF THIS DOCUMENT

ACRONYMS

AECC: Agri-environment climate Commitments

AECM: Agri-environment climate measure

ANC: Areas of Natural Constraint

AOI: Area Of Interest

AQL: Acceptance Quality Limit

BPS: Basic Payment Scheme as referred to in Title II of Regulation (EU) No 1307/2013

BUNDLE: panchromatic and multispectral image bands (of an image dataset)

CAPI: Computer Assisted Photo-Interpretation (CwRS)

CART: Classification And Regression Tree

CD: Crop Diversification

CwRS: Control with Remote Sensing

CY: Claim Year

DEM: Digital Elevation Model

DOP: Dilution Of Precision

DSM: Digital Surface Model

EFA: Ecological Focus Area

G4CAP: G4CAP is the Web-based application used to manage the whole campaign workflow

GAEC: Good Agricultural and Environmental Condition

GNSS: Global Navigation Satellite System

GSD: Ground Sample Distance

GSM: Global System for Mobile Communications

HDOP: Horizontal Dilution Of Precision

HHR: High High Resolution sensors (enhanced spatial resolution compared to HR)

HR: High Resolution sensors

J(e)PG: Joint Photographic Expert Group

LPIS: Land Parcel Identification System

MEA: Maximum Eligible Area

MS: Member States

MSP: Multi spectral GI raster

OTSC: On-The-Spot Checks

PA: Paying Agency

PAN: Panchromatic GI raster

PDOP: Position Dilution of Precision

PG: Permanent Grassland as referred to in Art. 4 of Regulation (EU) No 1307/2013

PG-ELP: Permanent Grassland under Established Local Practices

RA: Risk Analysis

RAnF: Ratio of Area not Found

RF: Risk Factor

RFV: Rapid Field Visit

RMSE: Root Mean Square Error

RP: Reference Parcel

RPAS: Remotely Piloted Aircraft Systems (drone)

RS: Remote Sensing

SAPS: Single Area Payment Scheme as referred to in Title III of Regulation (EU) 1307/2013

SF: Shape Factor

SFS: Small Farmer Scheme as referred to in Title IV of Regulation (EU) 1307/2013

SMR: Statutory Management Requirement

TI(F)F: Tagged Image File Format

UAV: Unmanned Aerial Vehicle (See RPAS)

VCS: Voluntary Coupled Support

VHR: Very High Resolution sensors

VHR+: Enhanced characteristics compared to Very High Resolution

YFS = Young Farmer Scheme

TERMINOLOGY

Beneficiary: as referred to in Article 2(1) of Regulation (EU) No 640/2014;

Control population = beneficiaries applying for an area-related aid scheme;

Control population for greening = beneficiaries required to observe the greening practices and who are not exempted or who are not participating in a certification scheme;

Control sample = sample of beneficiaries selected for an on-the-spot check;

Established area: Area of EFA resulting from direct field measurement or from delineation using ortho-imagery;

Greening payment = the payment for agricultural practices beneficial for the climate and the environment as referred to in Chapter 3 of title III of Regulation (EU) No 1307/2013;

Random sample = group of beneficiaries selected randomly;

Risk-based sample = group of beneficiaries selected on the basis of a risk analysis.

2 Overview

The overall process of OTSC is provided in figure 1 following a chronological approach. The different steps will constitute the chapters of the current document. A general timing and responsibilities for the different steps of CwRS campaign is also provided in table 1.

Member State administrations have to define their OTSC strategies and methods in such a way as to ensure effective verification of the correctness and completeness of the information provided in the aid applications and to ensure compliance with eligibility criteria and other obligations (Article 24 of Regulation (EU) No 809/2014). To do so, administrations are advised to reflect on, not being an exhaustive list, the geophysical/landscape particularities of the country, the different farm typologies, the staff and budget availability, the typologies of the different payment schemes, etc.

Farmers are required to submit their annual subsidy applications in prescribed form and by dates set in line with the Regulation. A sample of the whole population concerned by each payment scheme has to be controlled On-The-Spot. The check of the selected applications can be based on farm visit, or on satellite or aerial remote sensing data, or on a combination of these methods. Part of the OTSC work can be done through the use of external contractors.

Prior to the actual performance of checks, it is necessary to ensure a crucial step of data and tools collection and preparation.

Then the real work of OTSC of selected applications can take place. When using Ortho imagery (CwRS), each agricultural parcel will be categorized separately by applying the decision tables established by the Administrations to reflect the diagnosis concerning the area, the land use, the land cover, the GAEC, and the Rural Development measures according to the decisions of the Member State.

The photo-interpretation of agricultural parcels will normally be carried out using at least one very high resolution (VHR) image - aerial orthophoto or satellite ortho-image with a pixel size <=0.75m (preferably <=0.50m if dealing with small Landscape features) - of the current year to allow the area check of agricultural parcels. Their land use, wherever necessary, will be checked with the addition of a second VHR image but preferably with a set of multi-temporal high resolution (HR) images. The latter can be Sentinel2, HR or HHR. Sentinel1 data (SAR) can also be used. Attention should be paid to the fact that SAR (Synthetic Aperture Radar) data processing requires skills and knowledge different from optical. Please refer to the dedicated chapter in the technical guidance for OTS check of Crop Diversification.

In the case where the diagnosis may not be completed by Computer-Aided Photo-Interpretation (CAPI) procedures alone, the contractor or the Administration should trigger a follow-up action for checking the land use and/or some other issues. Usually, it has consisted in carrying out "rapid field visits" (RFV). However, administrations should also consider the possibility to use alternative solutions to capture data and/or gather evidences for the management and completion of dossiers such as the use of geotagged photos or RPAS (drones).

Administrations may also opt for the use of only one VHR image to check areas and perform a field visit to check the land use and/or some other issues on all selected parcels (so-called: Systematic Rapid field visit).

Following the parcel checks, dossiers will be categorised at payment group level and then at dossier level. Unless specified otherwise, the contractor will participate only in the stages related to the analysis of the remote sensing imagery completing the diagnosis. The penalty calculations, sanctions or financial consequences for the farmer are the responsibility of the Administration.

For each dossier inspected OTS, a report has to be produced to document all steps, findings and results. Attention should be paid to any finding that could trigger an Land Parcel Identification System (LPIS) update.

At the end of each OTSC campaign, it is highly recommended to perform a work of analysis of the results of the campaign. That consists in doing: a Quality Check (internal and/or external) of OTSC work (both field and CwRS) by re-performing the checks of a set of dossiers; an analysis of the error rates obtained and the main causes that led to these errors. Lessons learned should be capitalised to fine-tune, update if not upgrade OTSC methods for the following OTSC campaign.

The Commission's contribution to the OTSC programme is restricted to the technical coordination of methodological choices and the provision of satellite imagery for control zones defined by the Member State. Since 2007, the quality control procedure is the responsibility of the Member States. The JRC offers the possibility to support Member States in performing a QC of CwRS work on one (or two) CwRS zone(s).

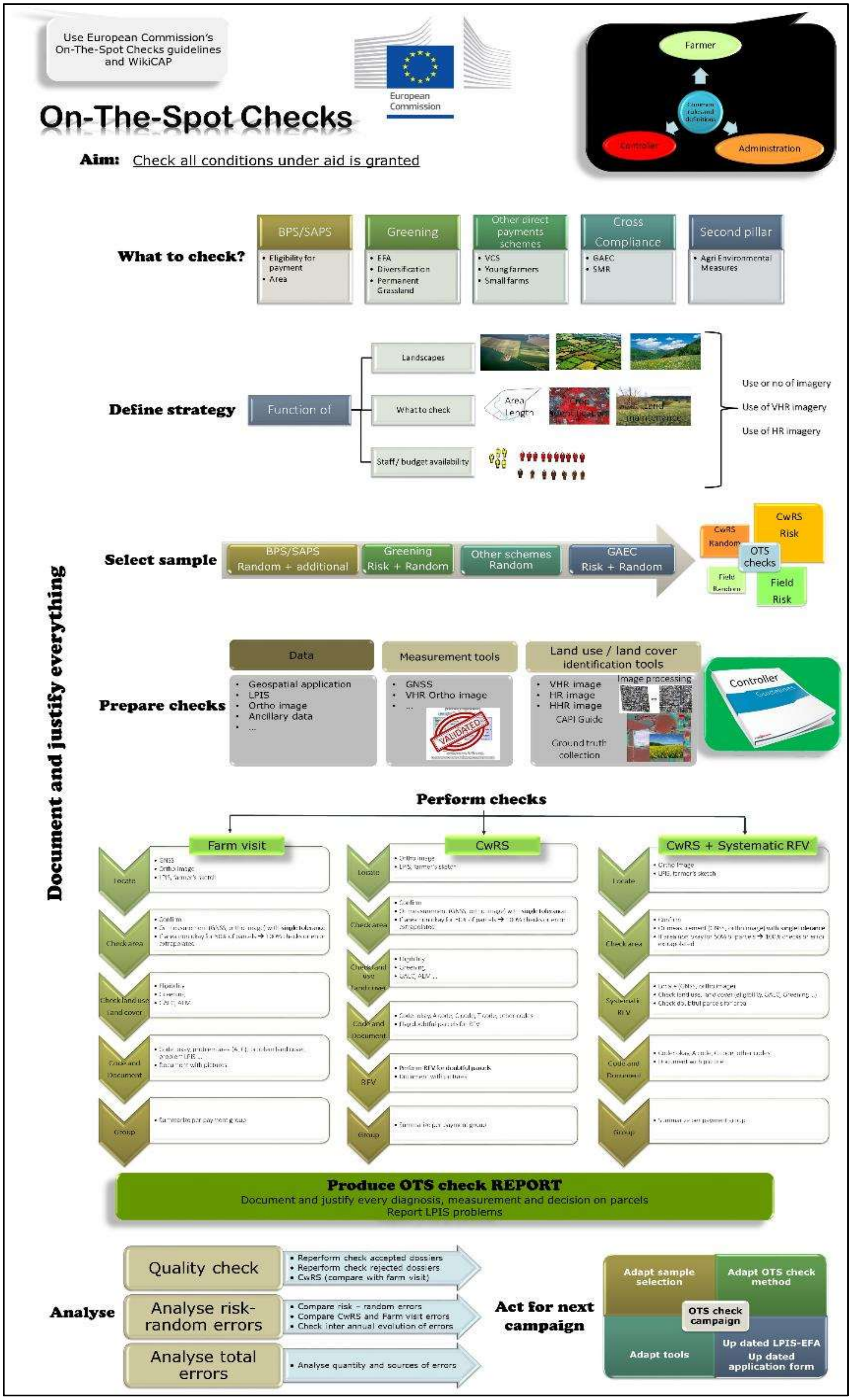

Figure 1: Overview of the OTS checks processes

Table 1: Main stages of a CwRS campaign

Responsible	Description	Period
	Preliminary work	
Administration MS	Selection of control zones, assessment of image requirements (interfacing within the web based system G^4CAP) Publication of Technical Recommendations	September-January
Administration MS	Call for tenders, selection of contractors, signature of contracts	December- March
Commission	Updating of technical documentation in WikiCAP and on G^4CAP	All year long
Administration MS	Selection and administrative processing of applications lodged in the control zones; transfer to contractors of dossiers and data bases (declarations, digital LPIS and LPIS ortho-images)	April- June
Contractor	Collection of applications data, LPIS vectors and farmer's sketch maps	March- June
	Preparation of data	
Commission/ Contractor	Acquisition of satellite images (Commission) and/or aerial photographs (Administrations/Contractors), processing, geometrical correction etc.	From October until the end of the campaign
	Photo-interpretation and categorisation of applications	
Contractor	Photo-interpretation of parcels to be checked	May- August
Contractor	Categorisation of applications and return of results	June- August
	Administrative follow up	
Administration MS	Follow up inspections in the field (if included in CwRS strategy)	July- October
Contractor	Contractor's report to Administration and discussions of results; return of summary statistics and images (rectified) to the Commission;	October-December
Commission	Possible visits to contractor and Administration on request by a MS	January – September

3 Documentation, justification and decisions sharing

The implementation of the CAP legislation is almost entirely the full responsibility of Member State administrations. Indeed, following the last CAP reform, more responsibility than ever has been given to Member States for the definition and/or decision of many components of the CAP system (e.g. minimum farming activity, list of EFAs, list of GAECs, and definition of a tree …).

When a Member State is audited (DG AGRI audit services, European Court of Auditors, etc.) the main aim of auditors' work is to check that the management and control system set by the Member States is reliable and effective (i.e. ensuring a minimum level of residual error and at the same time meeting the policy objectives). Different solutions may be considered to set a method, and many elements of the IACS may lead to weaknesses in the system.

So, administrations are recommended to document, justify and provide evidence as to their different choices, decisions and actions.

It is also very crucial that procedures decided, and decisions and rules set, are very widely shared between all IACS stakeholders: Administration, controllers, farmers (and Commission on request).

Commission guidance, technical guidance and WikiCAP webpages can obviously be used for that purpose. However, it is again recommended to develop and make use in each Member States of solutions like:

- Dedicated website providing all information on the IACS;
- Webpages dedicated to FAQ (frequent Asked Questions);
- Production of thematic Leaflets or booklets (the application system, the different payment schemes, the EFA list, definition and rules, The GAEC list definition and rules …);
- Production of "Controller guide";
- Organisation of trainings and/or information days;
- Use of Farm Advisory Service.

4 Campaign preparatory work

4.1 Define strategy

Member State administrations have the entire responsibility and a large autonomy to define their OTSC strategy. Strategies and methods should be set with the sole aim to ensure effective management and verification of the correctness and completeness of the information provided in the farmers' aid applications.

In financial term, an effective administration and control system should lead to an overall error rate below a materiality threshold of 2 % (European Court of Auditors criterion).

There is no ONE single OTSC strategy fitting all farmland situations in Europe.

The definition of sound strategies requires a good knowledge and analysis of the Member State and/or Regions farm structure and farmland characteristics. To do so, administrations should make use of GIS technologies.

Different layers and data set (e.g. LPIS layer, EFA layer, digital applications, road network layer …) could be combined and queried to help optimising field checks organisation, defining CwRS strategies, performing risk analyses, and optimising CwRS imagery use.

In addition, administrations can make use of the different results and findings of Quality Checks (see dedicated chapter), the LPIS Quality Assessment (see LPIS QA WikiCAP pages), or even the residual errors to adapt and fine-tune their control strategies.

4.2 Sample selection

On the 1st of January 2015 entered into force a new system of selection of the samples to be OTS checked for the different payment schemes (BPS/SAPS, Greening, VCS, SFS ...) and policy measures (Cross Compliance, Rural Development measures …). Selections are now mainly random based. Some elements (e.g. 'Greening', Cross compliance …) also include a risk based part. Note that as from the 1st of January 2018, the Reg. 809/2014 has been amended. The 'cascade system' in place has been deleted and replaced by new sampling requirements

A. Random selection

- The random sample concept

A random sample permits an estimate of the background level of anomalies in the system. It supports decisions enacting the mechanism for increasing the control rate (in accordance with Art.35 of Regulation (EU) No 809/2014) and also permits an assessment of the effectiveness of the criteria being applied for risk analysis.

There are several types of random samples, as well as different methods for compiling the random samples. For more details, please refer to section 1.3.2 of document *DS/CDP/2018/10.*

B. Risk analysis and annual assessment

According to Art. 34(5) of Regulation (EU) No 809/2014, MS are responsible for the definition of the risk criteria to be used for the risk analysis. It is the MS' responsibility to assess the effectiveness of the risk analysis on an annual basis and to update it by establishing the relevance of each risk factor. For further details, refer to section 1.4 of *DS/CDP/2018/10.*

The risk factors can be qualitative (e.g. region/district/department …) or quantitative (e.g. area declared, ratio of crops, EFA declared, number of participating schemes…). It is worth noting that risk factors might be different among schemes and/or among the MS. The only constraint is that each risk factor must be known for each beneficiary in order to assess his/her own risk.

Depending on the scheme, several variables are influencing both the reductions and the penalties systems. However, for area related subsidies and for 'greening' measures, the ratio of "area not found" (RAnF), i.e. the total area not determined in the relevant crop group/EFA over the total declared area for the same crop group/EFA, is a common parameter. For the crop diversification (CD) in the 'greening', the other parameters are the declared shares of each crop within declared arable land.

For this, MS can use a CART model (i.e. Classification and Regression Tree) with the area not found in individual claims as the dependent variable (i.e. the variable to be predicted). The CART model relies on a set of independent variables (i.e. the explaining variables; here, the potential risk factors) in order to find homogeneous sub-groups of the population (called the "nodes"). Advantages of the CART model are that it is:

- Well implemented in various statistical software (e.g. Matlab, R, S+, …);
- Relatively easy to apply (it only requires the input of the dependent variable and the potential risk factors);
- Flexible (no assumption is made how the potential risk factors are affecting the dependent variable);
- And irrelevant risk factors are automatically excluded from the model.

When calibrating the model, attention must be paid to the maximum level of the tree (i.e. maximum number of consecutive nodes) and the minimum number of observations in a node (generally at least 50).

After calibrating the model, a procedure named "pruning" is applied in order to remove the minor nodes in the tree. Ideally, the procedure is sequentially repeated to get simpler and simpler models. The final model is then chosen by optimizing criteria (e.g. minimum predicted variance on the validation set). If possible, the validation set should be independent from the calibration set (i.e. the individual claims that were used for the calibration should not be used for the validation).

Using the final CART model, it is possible to estimate the RAnF for each application and thus to estimate the discrepancy between the claimed area and the paid area (i.e. after deduction of the reductions and the penalties). These estimations on the whole population of beneficiaries can be used within the following alternative procedures:

- set a threshold determining the "low" and "high" risk sub-population, then select randomly within the "high" risk sub-population;

- as proxy for a probability-proportional-to-size sampling of the applications (ensuring thus to sample mainly the larger expected errors;

- regroup the applications with similar estimated risk (e.g. classes of discrepancy between claim and payment). A stratified random sampling can then be applied on these strata with a sample rate per stratum determined by the total risk of the corresponding stratum.

For instance, in the third alternative, a risk stratum that covers 30% of the total risk of the population (i.e. the sum of the estimated risk within this stratum is equal to 30% of the total sum of estimated risk) should represent 30% of the total sample size even if they are composed of only 10% of the total population. Knowing this sample size for the stratum, we can then translate it into a sample rate for the stratum. Thus, if the total population is 100k claims, the risk stratum above should be sampled as follows:

	# of claims (a)	% of claims (b)	Estim. Risk in ha for the strat (c)	Share of estim. Risk for the strat (d)	# of sample (e)	Sample rate within strat (f)
Highest risk	5k	5%	400 ha	40%	1.6k	32%
High risk	10k	10%	300 ha	30%	1.2k	12%
Medium risk	30k	30%	200 ha	20%	0.8k	2.7%
Low risk	55k	55%	100 ha	10%	0.4k	0.7%
TOTAL	100k	100%	1000 ha	100%	4k	4%

In the example, column (e) is computed as 4% x 100k x (d) (e.g. the first row is 4% x 100k x 40% = 1.6k), 4% being the objective risk-based sample rate (in the case of the population exempted from greening, the risk-based sample rate is 2.4%). That is the number of claims that must be selected in the stratum and put in the risk-based sample while column (f) is computed as (e)/(a) (e.g., for the first row is 1.6k/5k = 32%) and is the percentage of claims within this stratum that must be selected.

Comparison of the three suggested risk-based sample selection		
• **Risk-based selection method**	• **Pros**	• **Cons**

Comparison of the three suggested risk-based sample selection		
• Random selection within the "high risk" class only	• Optimal if the RA is perfect • Easy to implement	• High impact of the quality of the RA • Requires the choice of the threshold between "low" and "high" risks
• Proportion-to-size sampling	• Chances of selection proportional to its own risk • Each beneficiary has chances to be selected • Lesser impact of the quality of the RA	• Error rates might be less marked compared to those of the random sample
• Stratification of risk levels	• In principles, targets more the sub-populations representing the largest shares of risk • Lesser impact of the quality of the RA	• Requires to define the number of classes • Requires thresholds for the different classes • Error rates might be less marked compared to those of the random sample

4.3 Selection of Control zones

Contrary to classical checks, which can be individually geographically dispersed, in the case of CwRS, the areas where imagery is to be acquired need to be established. This clustering of checks is called a "control zone" with a geographical area defined on the basis of GIS analysis. It is worth noting that classical checks can also be organized in geographical clusters. The following descriptions can thus be arranged for any combination of classical checks and/or CwRS.

Despite the clusters, it is essential to ensure the representativeness of all conditions/ requirements of the targeted schemes and measures in the choice of the RS zones (see in particular Art. 34(2) last sub-paragraph of Regulation (EU)

No 809/2014). This is particularly true as RA is mainly foreseen to be used for the greening samples. In the past, the Commission services used to recommend opting for a high number of zones of small size. However, with the different changes in the legislation, this recommendation needs to be reassessed by taking into account the regional conditions within each MS. The optimal combination of number and size of zones is highly dependent both on the spatial extent and spatial integration of the farms in the landscape.

- The spatial extent is influenced by the size of the farms and the distances between the agricultural parcels of each farm;
- The spatial integration of the farms in the landscape is characterized by the spatial overlap of the farm extents.

Figure 1 illustrates the 4 possible scenarios summarizing the different combinations of spatial extent and spatial integration of the farms. Clearly, for the same number of controlled farms, a landscape characterized by large spatial farm extents with small overlaps will require larger images than a landscape characterized by small spatial farm extents with high overlaps.

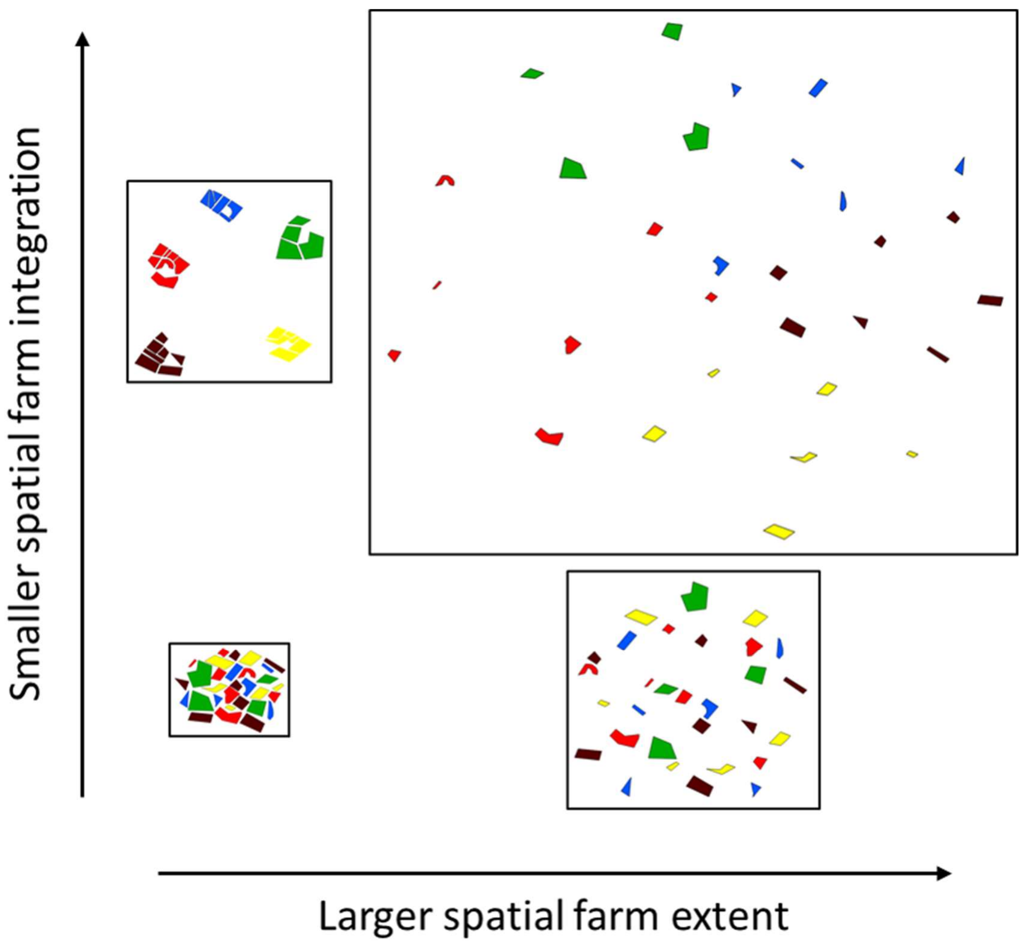

Figure 1: Influence of the farm spatial structure and integration on the required image size for CwRS.

It is reminded that the location of the zones shall remain confidential. In case of the use of contractor, zones should not be disclosed until a contract has been awarded.

The RS zone can be selected randomly or on the basis of a risk analysis. The selection possibilities are detailed in section 1.5 of document *DS/CDP/2018/10*.

- *For the selection of dossiers*

For the selection of dossiers, and especially for zones to be checked with satellite images to be acquired on Commission budget, attention has to be paid to the cost/benefit of such imagery (for this the spatial analysis as seen in Figure 1 is also relevant).

For instance, even if no thresholds are currently imposed by the Commission (i.e. no min and max number of dossiers per zone), it is recommended to look for the optimisation of parameters like the total area of applications to be checked inside the total Area of Interest (AoI) of images. For areas with very few dossiers, classical OTSC should be preferred.

- *In case of contractor*

After the phase of samples selection, approximate figures on the number of dossiers and zones should be given in the National Addendum. The approximate size of the zones should also be given by the Administration to the bidders. These figures, that should be taken as provisional, are intended to help the bidders assessing their workload. Also, in order to help the bidders determining a mean cost per application, the Administration should indicate the mean number of parcels per application and per zone, if requested by the bidders, as this number may vary significantly between regions of a given Member State.

4.4 Suggestion of an iterative procedure for the selection of control zones and samples

DG JRC suggests to rely on the following procedure for the selection of both the control zones and the different OTS samples (random and risk). The procedure is in line with the "cascade" sampling and can be applied for any combination of classical checks and/or CwRS. In the description of the procedure, it is assumed that the RAs have already been conducted so that the risk associated to each individual beneficiary can be evaluated. The description is made for the BPS/SAPS population but can be translated to other schemes (e.g. second pillar).

Step 1: Anticipatively estimate the required number of controls for each considered scheme accordingly with the beneficiary population. For instance, the share of the initial random selection is 20% (1% out of 5% of the controls), while the expected share (noted Sg% hereafter) of the 'greening' risk-based sample is the ratio between the number of risk-based 'greening' sample on the total number of controls (i.e. 5% of the population);

Step 2: Select randomly a control zone;

Step 3: Apply the "cascade" sampling on the zone using the expected shares computed in Step 1. In principle, all the beneficiaries of the control zone could be selected for controls in any of the different schemes. By doing so, the cost efficiency is guaranteed. However, this is not mandatory and the beneficiaries that remain unselected can be put in a reserve list for completing the sample at a latest stage;

Step 4: Add the different samples to the samples already selected on the previous control zones and check whether the target sample sizes are reached;

Step 5: If all the target sample sizes are reached, stop the procedure.

Otherwise, repeat Steps 2 to 4 until all sampling targets are met.

In addition, it is recommended to:

- Consider to pre-select a slightly larger sample in order to guarantee that the target sample size will be reached;
- Make the pre-selection estimation on slightly smaller zones than the final zones to increase the chances that the beneficiaries can be controlled (especially when using CwRS);
- Consider the possibility to switch from CwRS to classical checks if the control zone covers only few beneficiaries;
- Consider to select the last control zones in accordance with your needs. For instance, if the risk-based 'greening' sample is under represented, you might want to select the last control zone(s) by RA.

5 Preparation of checks

In order to check the conditions under which an aid is granted it is crucial to ensure a comprehensive step of tools preparation and data gathering, pre-processing and processing.

5.1 Reception of applications and data entry

From 2018 onwards, all farmers will have to provide information for their aid applications and payment claims, via a GIS-based interface (the geo-spatial aid application - GSAA). See guidance document on aid applications *DSCG/2014/39 FINAL-Rev 1*.

In view of facilitating the submission by the beneficiaries and to reduce the risk of errors, Member States shall provide pre-established digital forms. Through these forms, it is advised to provide as much information as considered useful based on diagnoses and checks made on parcels in the previous year as well as any relevant recent ancillary graphic material.

Furthermore, to limit errors, it is recommended to avoid to require free text information. Farmers should provide information via drop-down menus or tick box lists using pre-defined common options and nomenclatures.

If an administration makes use of a contractor, the applications will be transmitted to the contractors in digital form, after having been subjected to consistency checks, and possibly under an anonymous form. The format of the database given to the contractor will be described by the Administration, and accompanied by a list of the codes to be used.

5.2 Collection of LPIS data and other ancillary documents

Access has to be prepared and made available to the controllers for the relevant parts of the LPIS and EFA layers (i.e. the reference vectors, as well as the reference areas) and if any, the associated orthoimages. The applications to be controlled should contain appropriate cartographic documents allowing to locate all agricultural parcels, and, if applicable, all required EFA elements on the ortho-images or inside reference parcels.

5.3 Provision of satellite images

Since 1993, DG AGRI has promoted the use of "Controls with Remote Sensing" (CwRS) as an appropriate control system suitable to check if aids are correctly granted. Following the Council Regulation (EC) 1306/2013 (Articles 6(b), 21) and in its implementing regulations No. 908/2014 (Article 26), No. 809/2014 (Articles 24, 38, 39, 40), and No. 2333/2015. On this basis the Commission Services are required to centralize the Satellite Remote Sensing (SRS) image acquisition. This task was transferred to DG JRC in 1998 (September 1998/VI/34942) and it is managed through a horizontal co-delegation (Type I) between DG AGRI/DG JRC (via DG BUDG) (ref. Ares(2015)1215220) to implement the yearly CAP image acquisition work programme

Concerning the timing of the operations, article 26 of the Commission Implementing Regulation (EU) No 908/2014 states that:

> 1.) For the purposes of Article 21 of Regulation (EU) No 1306/2013, each Member State shall inform the Commission by 1 November of each year at the latest, as to:
>
> (a) whether it wishes the Commission to acquire the satellite images necessary for its programme of checks and/or for its Land Parcel Identification System Quality Assessment;
>
> (b) the area to be checked and the number of planned control zones.
>
> 2.) Member States requesting the Commission to obtain the satellite images shall finalise, in cooperation with the latter and before 15 January following the communication of information referred to paragraph 1, the zones to be covered and the timetable for obtaining those images

It is reminded here that, if a Member State has opted for the implementation of monitoring instead of the OTS checks, it shall have notified the Commission by 15 September of the calendar year preceding the calendar year in which they start carrying out checks by monitoring.

For more information, see the working document DS/CDP/2017/08, on a proposal to amend the Implementing Regulation (EU) No 809/2014.

With reference to Table 1 of Chapter 1, MS Administrations shall insert at first their pre-Image Requirements (pre-IRs) by the 1st of November, and then the final detailed image requests by the 15th of January in the web application G^4CAP in accordance with above deadlines.
For details on the web application G^4CAP used to synchronise all stakeholders in the satellite image acquisitions for the CAP please refer to: https://g4cap.jrc.ec.europa.eu/g4cap/.
One has to note that:

1.) For all interactions, user/pwd (credentials) will be requested to and assigned by JRC;

2.) manuals can be found under 'Documentation' menu where no credentials are needed.

5.4 Management of satellite image acquisition

All instructions valid for the stakeholders (or Actors) participating in the CAP image acquisition: DG AGRI, DG JRC, MS Administrations, MS Administrations' contractors, FW contractor/s (with their two roles: operator and image provider) are given in the technical image acquisition specifications for the CAP checks which are updated every campaign.

These specifications are divided into the VHR and the HR specifications. The specifications details are available on the G^4CAP website.

The image acquisition process described follows the workflow in the figure below. To be read together with the colour legend of responsible actors.

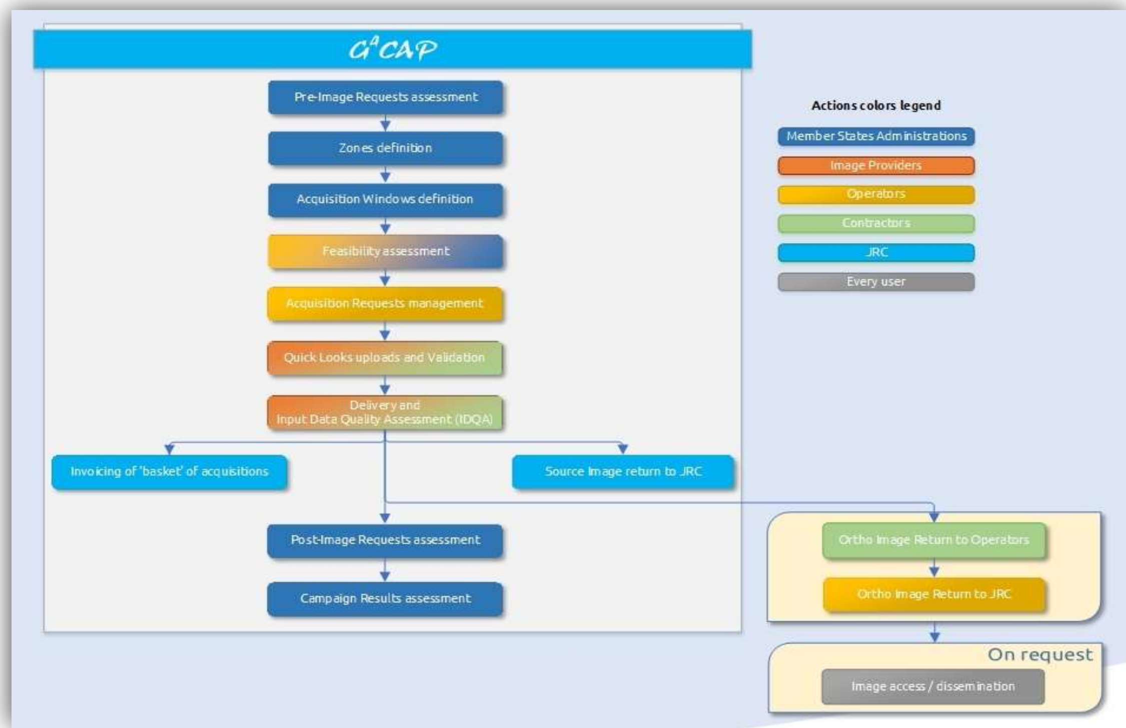

Figure 2 – The satellite image acquisition process with relevant responsible actors

Use of Copernicus datasets

The MS Administrations and their contractors should possibly make use of the Copernicus infrastructure sensors Sentinel1 (SAR) and Sentinel2 (optical), and its DataWareHouse (DWH) datasets.

The Sentinel datasets are free of charge and openly accessible[3]. The EC strongly encourages using all cloud free S2 images wherever useful in their CAP controls. Sentinel 2 (A and B) satellites have a wide swath width and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites (2A and 2B) under cloud-free conditions which results in 2-3 days at mid-latitudes. (i.e. up to 12 passes per 'normal' length CwRS window).

It is up to the MS Administrations to download S2 data from ESA or elsewhere. However the JRC makes available the 'S2 alert module' accessible from within the G4CAP web application where the user can be alerted and given the access URL

[3] S1/S2 accessible freely from the ESA scientific hub: https://scihub.copernicus.eu/

whenever there is a suitable S2 imagery acquired over a defined control zone over a defined window.

The DWH datasets follow a licensing agreement that may allow download (DL), or VIEW, freely for Public Authorities[4], after registration to the Copernicus Space Component Data Access (CSCDA). These DWH datasets include a vast number of CORE and ADDITIONAL datasets, including pan EU HR and VHR coverages which are renewed every 3 years, and can be used most suitably in preparatory work for the CAP controls.

Also, the EC strongly encourages using Sentinel1 data as part of the CAP checks process. However, since S1 A and B are all-weather, day-and-night SAR imaging satellite, data availability (also here 3-4 days revisit time) over a specific CwRS zone is known and there is no need for an 'alerting system'.

5.5 Acquisition of aerial imagery (if applicable)

Acquisition of aerial imagery for the checks is the responsibility of the MS Administration, i.e. it is not coordinated by the Commission. The main advantage of aerial imagery with respect to VHR satellite imagery is that it allows covering much larger areas (e.g. large administrative units such as full provinces) in a relatively limited period of time. Alternatively, a large number of small zones may also be covered in a given region.
However, acquiring aerial imagery has also some proper constraints such as restrictions over military zones and air traffic lanes. Cloud cover is not as restricting for aerial photography as for satellite imagery, but meteorological conditions are in any case affecting the radiometric quality of the images.
Moreover, the lead-time in the acquisition-processing of aerial imagery may be longer than that for satellite images. Aerial images acquisition must therefore be organised sufficiently in advance, and the acquisition periods should be relatively early in the year. The use of (natural colour in combination false colour composite) imagery permits an easier identification of land covers, thus significantly reducing follow-up rapid field visits for crop identification.

It is also compulsory that aerial flights is carried out within the present state of the art: the use of GNSS GNSS-inertial navigation systems linked to the camera makes it possible to optimise the flight coverage and considerably reduce the costs of further processing.

If Administrations and/or contractors intend to acquire and/or ortho-rectify aerial digital imagery, they should refer to the Best Practice and Quality Checking of Ortho Imagery JRC guidelines[5].

[4] DWH (CORE datasets …) of the Copernicus Space Component Data Access (CSCDA): **https://spacedata.copernicus.eu/**

[5] https://g4cap.jrc.ec.europa.eu/g4cap/ (under Documentations menu)

To safeguard EU funds and since aerial image acquisitions are not coordinated by the Commission, it is the responsibility of the MS administrations to avoid situation of acquisition of VHR satellite imagery contemporaneously to an aerial acquisition.

5.6 Processing of satellite and/or aerial images

The person in charge of image processing should record and substantiate all steps and all processing techniques used: geometric ortho correction, radiometric correction, contrast stretching, resampling, pan sharpening, mosaicking.

A. Geometric correction

The Commission does not impose a methodology for geometric correction of imagery, but gives recommendations and guidelines in line with its Quality Assurance (QA) strategy described in the Guidelines for Best Practice and Quality Checking of Ortho Imagery. The philosophy is to have a set of suitable procedures to ensure a satisfactory quality of the product. These guidelines are to be considered as the Commission's current understanding of "best-practice". It must be clear, however, that in the end the administration/contractor alone is responsible for the accuracy of products.

The entity in charge of image processing needs to have appropriate software suite (or sub-contracting options), and "know how" to process all image types (i.e. be able to ortho-rectify all image types, pan-sharpen bundle images, etc.).

The allowed geometric error in the output images (and associated Digital Elevation Models, DEM) are expressed as a maximum permissible absolute (i.e. with respect to a specific geodetic reference frame) Root Mean Square Error (RMSE) with respect to well-defined and independent check points, and are stated in the Technical Specifications mentioned above. The geometrically corrected products and associated DEMs are assessed separately in three geometric dimensions i.e. RMSEx, RMSEy, and (where relevant) RMSEz.

Since 2014, the EC has introduced the use of different profiles included under the HR and VHR umbrellas. These are images with varying characteristics allowing the MS Administration to use the most suitable imagery for their specific agricultural landscape and scheme to be controlled.. They are therefore sensor independent profiles, fitting the CAP VHR and HR image specifications in terms of spatial resolution, radiometric resolution, number of spectral bands, geolocation accuracy/absolute geometric accuracy achievable in orthorectification, elevation angle, programming type, processing levels, and cloud cover threshold over the control zone (AOI) etc.

The profiles are further explained in the VHR/HR Image Acquisition specifications. It is essential that the MS Administrations or their contractor conform to these guidance. Below figure shows a summary of the VHR and HR profiles.

Image Profile ID	Description	Spatial resolution requirement (*)	Radiometric resolution (**) and spectral bands	Minumum Elevation Angle restriction (***)	Cloud Cover (CC) over AOI	Acquistion programming	Resampling	Remarks	Example of sensors
A1. VHR prime - CwRS [std]	Pan+Multispectral (Bundle)	GSD≤0.75m	PAN	> 50	≤10%	Priority programming	sensor dependent	standard CwRS profile	WV4,WV3,WV2, GE1, K3, possibly others not benchmarked yet
		GSD≤3m	MS (at least 4 bands)						
	Pan-sharpened	PAN GSD≤0.75 m, MS GSD≤3 m	at least 4 bands						
A11. VHR prime - CwRS [VHR+][8]	Pan+Multispectral (Bundle)	GSD≤0.75m	PAN	> 50	≤10%	Priority programming	0.50m		WV3, WV2, possibly others not benchmarked yet
		GSD≤3m	MS (at least 8 bands)				2m		
A12. VHR prime - CwRS [VHR+][16]	Pan+Multispectral (Bundle)	GSD≤0.75m	PAN	> 50	≤10%	Priority programming	0.50m		WV3, possibly others not benchmarked yet
		GSD≤3m	MS (16 bands; 8 SWIR bands may have coarser resolution)				2m		
A2. VHR prime - [Topographic] [less strict than A5]	Pan+Multispectral (Bundle)	GSD≤0.75m	PAN	> 56	≤10%	Priority programming	sensor dependent		WV4,WV3,WV2, GE1, K3, possibly others not benchmarked yet
		GSD≤3m	MS (at least 4 bands)						
	Pan-sharpened	PAN GSD≤0.75 m, MS GSD≤3 m	at least 4 bands						
A3. VHR prime - CwRS [Pan only]	Pan	GSD≤0.75m	PAN	> 50	≤10%	Priority programming	sensor dependent		WV4,WV3, WV2, GE1, WV1, possibly others not benchmarked yet
A4. VHR prime - CwRS [Stereo]	Pan+Multispectral (Bundle)	GSD≤0.75m	PAN	according to IP specifications	≤10%	Priority programming	sensor dependent		WV3, WV2, GE1, possibly others not benchmarked yet
		GSD≤3m	MS (at least 4 bands)						
	Pan-sharpened	PAN GSD≤0.75m, MS GSD≤3m	at least 4 bands						
A5. VHR prime - CwRS [VHR+Topographic]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 67	≤10%	Priority programming	0.40m		WV4,WV3,WV2, GE1, possibly others not benchmarked yet
		GSD≤2m	MS (at least 4 bands)	> 67			1.60m		
	Pan-sharpened	PAN GSD≤0.50 m, MS GSD≤2m	at least 4 bands	> 67			0.40m		
A51. VHR prime - CwRS [VHR+Topographic][8]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 67	≤10%	Priority programming	0.40m		WV3, WV2, possibly others not benchmarked yet
		GSD≤2m	MS (at least 8 bands)	> 67			1.60m		
A52. VHR prime - CwRS [VHR+Topographic][16]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 67	≤10%	Priority programming	0.40m		WV3, possibly others not benchmarked yet
		GSD≤2m	MS (16 bands; 8 SWIR bands may have coarser	> 67			1.60m		
A6. VHR prime - CwRS [VHR_EFA_LF]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 50	≤10%	Priority programming	0.50m	new profile	WV4,WV3,WV2, GE1, possibly others not benchmarked yet
		GSD≤2m	MS (at least 4 bands)				2m		
	Pan-sharpened	PAN GSD≤0.50 m, MS GSD≤2m	at least 4 bands				0.50m		
A61. VHR prime - CwRS [VHR_EFA_LF][8]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 50	≤10%	Priority programming	0.50m	new profile	WV3, WV2, possibly others not benchmarked yet
		GSD≤2m	MS (at least 8 bands)				2m		
A62. VHR prime - CwRS [VHR_EFA_LF][16]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 50	≤10%	Priority programming	0.50m	new profile	WV3, possibly others not benchmarked yet
		GSD≤2m	MS (16 bands; 8 SWIR bands may have coarser				2m		

Image Profile ID	Description	Spatial resolution requirement (*)	Radiometric resolution (**) and spectral bands	Minumum Elevation Angle restriction (***)	Cloud Cover (CC) over AOI	Acquistion programming	Resampling	Remarks	Example of sensors
A7. VHR prime - near nadir profile [VHR_NN_50]; LPIS	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 80	close to cloud free, haze free, better than ≤10%	Image Provider (IP) best programming, when sensor available	0.50m	new profile; longer acquistion window: typically March-August; AOI chosen by IP within large areas given by JRC	WV4,WV3,WV2, GE1, possibly others not benchmarked yet
		GSD≤2.00m	MS (at least 4 bands)	> 80			2.00m		
	Pan-sharpened	PAN GSD≤0.50 m, MS GSD≤2.0m	at least 4 bands	> 80			0.50m		
A71. VHR prime - near nadir profile [VHR_NN_50]	Pan+Multispectral (Bundle)	GSD≤0.50m	PAN	> 80	≤10%	Priority programming	0.50m	new profile	WV4,WV3, WV2, GE1, possibly others not benchmarked yet
		GSD≤2.00m	MS (at least 4 bands)	> 80			2.00m		
	Pan-sharpened	PAN GSD≤0.50 m, MS GSD≤2.0m	at least 4 bands	> 80			0.50m		
A8. VHR prime - near nadir profile [VHR_NN_40]; LPIS	Pan+Multispectral (Bundle)	GSD≤0.40m	PAN	> 80	close to cloud free, haze free, better than ≤10%	Image Provider (IP) best programming, when sensor available	0.40m	new profile; longer acquisition window: typically March-August; AOI chosen by IP within large areas given by JRC	WV4,WV3, , possibly others not benchmarked yet
		GSD≤1.60m	MS (at least 4 bands)	> 80			1.60m		
	Pan-sharpened	PAN GSD≤0.40 m, MS GSD≤1.6m	at least 4 bands	> 80			0.40m		
A81 VHR prime - near nadir profile [VHR_NN_40]	Pan+Multispectral (Bundle)	GSD≤0.40m	PAN	> 80	≤10%	Priority programming	0.40m	new profile	WV4,WV3, possibly others not benchmarked yet
		GSD≤1.60m	MS (at least 4 bands)	> 80			1.60m		
	Pan-sharpened	PAN GSD≤0.40 m, MS GSD≤1.6m	at least 4 bands	> 80			0.40m		
B. VHR archive	as any of above	as any of above	as any of above		as any of above	Archive	sensor dependent	used for archive search for any profile	WV4,WV3,WV2, GE1, K3
	as any of above	as any of above	as any of above		as any of above	Priority programming	sensor dependent	used for re-task for any profile	WV4,WV3,WV2, GE1, K3
	as any of above	as any of above	as any of above		10%>CC≤30%	Priority programming	sensor dependent	proposed for any profile	WV4,WV3,WV2, GE1, K3
E. VHR back up	Pan+Multispectral (Bundle)	GSD≤3m	PAN		≤10%	Priority programming	sensor dependent	backup for any profile	WV4,WV3,WV2, GE1, K3
		GSD≤12m	MS (at least 3 bands)						
	Panchromatic	GSD≤3m	PAN						
	Pan-sharpened	GSD≤3m	at least 3 bands						

(*) GSD in both directions (across track, along track) including the effect of earth curvature should satisfy this criterium

(**) Dynamic range, minumum ≥ 11 bits/pixel

(***) Elevation angle (ELA) of any uploaded strip of an acquisition should satisfy this criterium

Fig 3 – VHR profiles adopted within the CAP checks

Image Profile ID	Description	Spatial Resolution	Radiometric resolution (*) and spectral bands		abs. 1-D rmse	Cloud Cover (CC) over AOI	Acquistion programming	Remarks	Example of sensors
F1. HHR prime - CwRS [HHR]	Pan+Multispectral (Bundle)	GSD≤3m	4 bands including B, G, R, NIR	> 50 deg	x,y ≤ 5m	≤ 1% validated (profile F11) ≤ 5% proposed (profile F12) ≤ 20 % retained (profile F13) -archive (profile F14)	Priority programming (excl F14)	new profile	SPOT 6/7
		GSD≤12m							
F2. HHR prime - CwRS [ORTHO]	Pan+Multispectral (Bundle)	GSD≤3m	4 bands including B, G, R, NIR	> 50 deg	x,y ≤ 5m	-≤ 1% validated (profile F21) -≤ 5% proposed (profile F22) -≤ 20 % retained (profile F23) -archive (profile F24)	Priority programming (excl F24)	new profile; ortho rectified using Ref3D	SPOT 6/7
		GSD≤12m							
	Multispectral	GSD≤12m			x,y ≤ 1.5 x GSD (MSP)				
	Pan-sharpened	GSD≤3m			x,y ≤ 5m				

(*) - minimum 8 bits/pixel, preferrably 11-12.
(**) - SPOT5 will be de-commissioned in March 2015

Fig 4 – HR/HHR profiles adopted within the CAP checks

In order to meet these specifications, the person in charge should carefully analyse the input data and particularly the **Digital Elevation Model (DEM)** to be used, the ground reference data (accuracy of Ground Control Points (GCP), independent checkpoints (ICP) used, their source, number and distribution) and each step of the geometric correction process. One should record all steps of this geometric correction process.

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*By Digital Elevation Model (**DEM**) it is intended a regularly-spaced raster grid, representing the **elevation of land surface,** referenced to a common vertical datum (usually the sea level). The artificial built-up (powerlines, buildings and towers) and natural (trees and other types of vegetation) features are voided and are not extruded in a DEM. Thus, it typically represents the **bare, ground surface of the earth**. This has to be distinguished from a Digital Surface Model (DSM) that captures and depicts the natural and built features on the Earth's surface (often costly to create using LIDAR system).*

*In some countries, **Digital Terrain Model** (DTM) will be used as a synonymous of DEM. However, in many other countries DTM has a slight different meaning. In the context of the CwRS, DTM is a vector data set composed of regularly spaced points and natural terrain features such as ridges and breaklines. A DTM represents land surface much better than DEM. Obviously, from these regularly-spaced points and breaklines, a DTM can be rasterized (gridded) into a DEM. Such augmented DEM, if available, **would be the one recommended** to use to produce the most accurate Ortho-rectified VHR imagery.*

B. Radiometric correction

Imagery checks, especially those conducted for the LPIS QA screening, revealed that the quality measures related to radiometry and photometry given in the JRC orthoguidelines and specification for orthoimagery needed some further clarification. Details are provided in Annex 1.

5.7 Ground data collection

As a support for the CAPI and/or as training set for classification of the satellite images, it is recommended to build a database of reference fields for the most common land use/crops in control zones. The survey(s) have to be carried out at the beginning of period(s) most appropriate for the land use/crops of interest (winter crops, summer crops, secondary crops, permanent crops, grassland management …). Surveys should ensure a good representation of the main land use/crops (for example, 5 to 10 parcels per crop type spread over control zones) and include, if applicable, some examples of infrequent land use/crops.

5.8 Production of a "controller guide" (CAPI guide and field control)

*One of the main elements influencing the accuracy of On-The-Spot checks results is the use of **appropriate tools and the use of tools appropriately**. Likewise, is the **consistency of the defined rules to identify, delineate and measure** features and crops of interest for the different CAP schemes.*

The production of a controller guide is thus crucial to document and share the defined rules among the different stakeholders (at least CAP administrators, controllers, and farmers).

In this guide, attention should be paid to the provision of clear feature specific identification rules applicable both on imagery and on the field. The basic assumption is that a specific feature on the ground remains obviously the same feature on imagery; thus, its delineation and/or measurement should come with the same result whether it is checked using imagery or in the field.

The guide should contain drawings and example pictures to illustrate specific cases; it should further provide information on possible ancillary data (archive imagery, river, transport networks etc.) that could help identifying and delineating features.

The guide should also contain the common praxis on how and what to report for the parcels and dossier under check.

5.9 GNSS and ortho image validation

The use of tools - whether ground or remote sensing based - for the measurement of agricultural parcel areas requires that all interested parties can expect reliable and trustable measurements.

*The JRC has developed and proposed a **method for the validation** of tools for area measurement, which can objectively assess the correct performance (under specified conditions) and attest therefore the tool as fit for the purpose of **parcel area measurements made in the context of field checks** required in Commission Regulation (see Annex 2).*

While not mandatory, it is highly recommended to Member States to validate their measurement tools through the JRC method. Alternatively, Member States can also:

- use a device tested and certified by an authorized entity;

- use a device tested and validated by a reference laboratory approved by JRC.

The full description of the JRC "Area measurement tool validation method" is provided in Annex 2.

6 Perform checks

The purpose of on-the-spot checks is to check the conditions under which aid is granted in accordance with Article 37 of Regulation (EU) No 809/2014. In summary, this means to check for each parcel declared: their location, area related aspects and land use/land cover related aspects. Diagnoses will be attributed at parcel level.

When using imagery, in case of non-conclusive opinion on a parcel, a Rapid Field Visit (RFV), or other follow-up (e.g. geotagged photo), shall be undertaken for completion of the diagnosis at parcel level.

Then, diagnoses at parcels level will be aggregated to provide a diagnosis at crop group and/or payment scheme level. Finally, a diagnosis will be provided at dossier level.

As a by-product of these checks, feedbacks to the LPIS should be made (e.g. using specific codes) wherever appropriate.

6.1 Check at parcel level

A. Parcel location

In the field, documents such as maps for the overall location of the parcels and detailed location documents (e.g. parcel boundaries overlaid on a VHR image) have to be provided to the staff in charge of the checks.

Alternatively, navigation systems based on GNSS and systems allowing the display of images, vectors and data on a mobile computer/tablet in the field may be used to locate and reach the parcel of interest.

On imagery, each declared parcel will be located on screen with the help of the **LPIS vector layers** (reference parcels, landscape features, EFAs,..) and the farmer's **sketch map** provided through the Geo Spatial Aid Application (GSAA).

It is important to locate and delineate all declared parcels, including those for which no aid is claimed, to detect possible multiple claims and to verify cross compliance issues.

B. Area check

The inspector should have received sufficient instructions and training, and be largely able to undertake the work autonomously. The inspector should have no conflicts of interest, and should be able to carry out the inspection independently. In order to provide a result to the appropriate precision and to ensure effective verification, the inspector must have access to appropriate claim data (including map information) and data collection/measuring equipment.

Also, as a general rule, the area of each subsidised agricultural parcel will be verified either on the field or on the current year VHR imagery (i.e. <= 0.75m pixel size). Unless requested otherwise by the Administration, the area of non-subsidised agricultural parcels will, in general, not be checked.

The result of the digitisation or field measurement will be the "measured" area, which will be compared to the "declared" area of the corresponding parcel. The results will be expressed as the area projected in the national system used for the LPIS and in hectares rounded to two decimal places.

Attention should be paid to the definition of the agricultural parcel attached to the crop group or payment scheme under check. The inspector/controller shall follow this definition when measuring parcels (see 'definition of agricultural parcel' chapter of *DS/CDP/2018/10*).

The total area of the agricultural parcel should be measured. However, areas not taken up by agricultural activities such as buildings, woods, rocks, some ponds and paths are to be excluded by deduction from this area.

To assess the eligibility of areas within an agricultural parcel of permanent grasslands, Member States can use a reduction coefficient (please refer to the Technical guidance on the pro rata system for permanent grassland).

Member States shall define beforehand the criteria and procedure used to delimit the (in)eligible part of the parcel in order to ensure that these criteria are communicated to farmers, correctly transposed, where necessary, in the LPIS and adequately included in the instructions for the on-the-spot checks.

In the office, on-the-spot checks need to be prepared by selecting the areas to be measured, grouping and/or subdividing the parcels declared with reference to the LPIS, and arranging visit itineraries as efficiently as possible to optimise holdings check time. The direct – preferably in digital form – consultation of the LPIS data (including where applicable orthophotos) shall be possible for the preparation of field controls.

The LPIS data should be available also for use during the on-the-spot checks.

Where features that are part of the good agricultural and environmental condition obligations or the statutory management requirements (e.g. hedges, drainage ditches, small woods according to the local regulations) have been specifically recognised and defined as (landscape) features eligible for area payment, they should not be excluded from area measurement. Nevertheless, it is recommended that, during the on-the-spot checks (i.e. remote sensing or otherwise), the inspector reports the presence of these features in the control file. Some EU MSs have digitised such features as points, lines or polygons with their corresponding attributes in the LPIS, this way making easier and more effective their management and control of their maintenance.

There are two options for measuring the agricultural parcel area: 1) direct measurement or 2) measurement by deduction, which is applicable only in particular circumstances.

The measurement by deduction can be done when the LPIS, together or not with other ancillary data such as ortho-photos, permits the confirmation of the boundaries of the declared agricultural area. Thus, the area measurement may focus on the determination of ineligible areas and deductions. This situation is only possible when:

- the LPIS reference parcel is an agricultural parcel; or,
- the reference parcel is fully declared; or
- use is made of geospatial declaration (or graphical material which is then transcribed in the GSAA in accordance with Article 17(3)(b) of Regulation 809/2014) of agricultural parcels, which allows an overlay of boundaries and eligible area as reported on the image;
- and areas not to be accounted (deducted) for can be easily identified.

In all other circumstances, a direct measurement of the parcel area (e.g. using GNSS or VHR ortho-image) is required.

For details on the deduction of ineligible features, please refer to section 3.2 of document DS/CDP/2018/10.

C. Material to be used for parcel area measurements

MS shall use measurement tools that are proven to assure measurement of quality at least equivalent to that required by applicable technical standard, as drawn up at Community level. In other words, accuracy of measurements must be at least equivalent to the accuracy needed for the management of geo referenced data at cartographic scale of 1/5.000. The quality of a given tool is defined by the tolerance (i.e. buffer width) applicable to this tool as determined through an area measurement validation test.

In concrete terms, only tools (e.g. GNSS equipment, remote sensing ortho-images) with a buffer width not exceeding 1 m should be used.

- Use of VHR ortho-imagery

If VHR imagery (i.e. pixel size <=0.75m) is used for parcel area measurement, current image shall be used. Recent archive VHR imagery can be used only if it enhances the interpretation primarily made on the current year VHR imagery, therefore helping the interpreter making the decision. It is reminded that VHR imagery should be accurately ortho-rectified (see corresponding section). For the delineation of parcel boundaries, a viewing scale of 1/1.000 would often be suggested. However, the interpreter should vary the viewing scale depending on size and type of parcel to be measured and store this information in the OTSC report.

Where reference parcels (LPIS parcels) contain several (full or partial) agricultural parcels, the CAPI operator will have to locate and digitize the declared agricultural parcels inside the LPIS parcels using the sketch maps attached to the farmers GSAA and taking account of the current definition of the agricultural parcel. Since farmers' sketch maps are only indicative, operators are advised to report cases where the retained area significantly exceeds the declared area so that complementary checks may be carried out by the Administration (particularly for dossiers where the possible excess of the retained area compensates for an under-declaration). Such cases may occur when the operator is not aware of all declared parcels in the reference parcel (e.g. as a result of the sample selection) or because some parcels may not be declared (e.g. because they belong to non-farmers).

- Use of Stand-alone GNSS devices

The GNSS equipment choice offered on the market is very wide, but not all devices meet the accuracy requirements imposed by the Regulation. Nowadays, most of devices come with dedicated packages allowing measuring parcel areas. If an Administration decides to acquire a new GNSS receiver, it is advised to perform an area measurement validation tests to know if it meets the required accuracy.

How to measure the area?

The general method to measure a parcel area consists in following the parcel perimeter with the GNSS device.

It is reminded that it is the ***GNSS antenna*** *that determines the physical geo-location of the device. So, the antenna should always be positioned and maintained at the vertical of the perimeter to be measured.*

The user should be aware of the possible difficulties that may arise during measurement, such as loss of satellite signal, multi-path effect etc.
Some of these difficulties can be reduced by an appropriate set up of parameters

like: signal to noise ratio (S/N), maximum Position Dilution of Precision (PDOP) and horizon mask.

In any case, a visual check of the parcel recorded should be systematically done to detect blunder points (see Figure below).

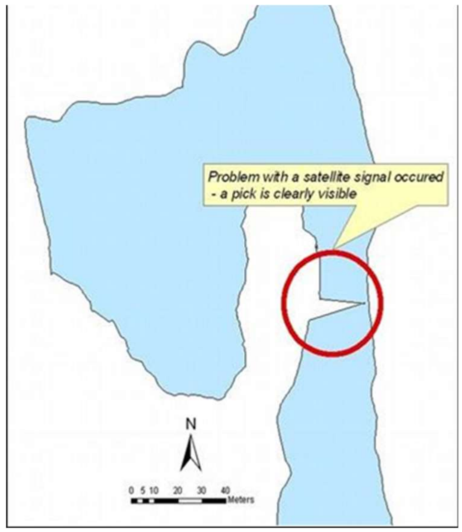
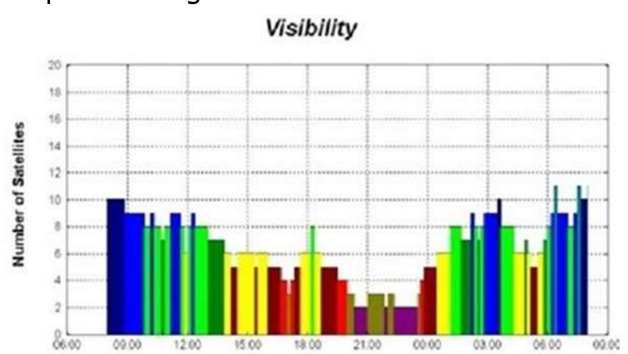


Figure . Example of an error connected with loss of satellite signal.

More generally, large discrepancies with the declared area should, in case of doubt, always lead to a second measurement.

Whenever the measurements need to be taken in a difficult area like a valley or neighbourhood of a forest, a measurement planning software is advised to be used. This software allows simulating the configuration of the GNSS system at a certain point and time of the day, month, year. As the position of satellites is changing in time, selecting the optimum time of the day for the measurement can help achieving a reliable result in a short time.



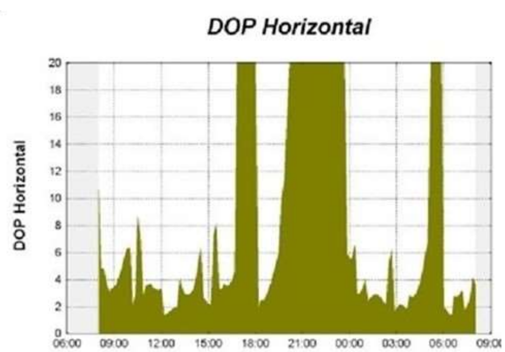


Figure left: Simulation of number of satellites in the certain position with some obstacles on the side.

Figure right. Simulation of the Horizontal Dilution Of Precision (HDOP) in the certain position with some obstacles on the side.

Some software are also able to take into account the features potentially blocking the signal from the satellites. This is done by introducing a simple sketch of the position of the obstructions influencing the test field in the software. The horizon is therefore reduced according to this sketch, making the simulation more realistic (see Figure 4.).

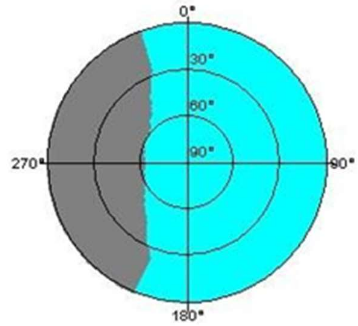


Figure: A sketch of the situation in the field. A feature blocking signal (in grey) on the west side of the object to measure.

Continuous measurements or logging vertices only?

The appropriate method of measurement as well as advice for optimizing the measurement accuracy are usually suggested by the manufacturer.

*Nevertheless, as a general rule, the use of the **continuous mode** is recommended as it increases the possible compensations between point position errors, thus also for squared or rectangular shape parcels. When elements (e.g. a wood or a hedge) obstruct the passage on the perimeter, it is advised to switch to the stop & go method.*

For parcels with very straight borders, one may decide to perform measurements with logging vertices (at each corner) method. However, it often proved not to be faster than the continuous measurement method, since several logging vertices must be recorded by corner. Also, possible compensations between point position errors will be reduced (so increase of possible measured area error) since the number of points will be significantly lower than with a continuous mode measurement.

Please note, that the result of the validation is strictly related to the tested method of measurement and not only to the device.

Therefore, it is strongly recommended to perform the GNSS validation test in both continuous and vertex methods.

An often commented fact is that the tracks of the measurements taken with the continuous measurements method look 'worse' (more noisy) on the screen of the device (and in the GIS) than the ones collected by logging vertices only. The purpose of the on-the-spot controls is to find the actual area eligible for payments and to verify the farmer's declaration in a fair way. Therefore, the reliability of the measurement and the best practice in taking the measurement should be a priority over the 'sharp' shape of the field. In other words, the method of the measurements should be adjusted to the tool and conditions of the measurements rather than to the preferences for seeing 'straight' borders in the GIS database.

- Use of differential GNSS, geodetic survey GNSS receiver or total station

These types of devices are more expensive than standalone GNSS, they require more expertise to use them and require more preparation time to have them up and running. However, these instruments allow to obtain accuracy at centimeter level. Thus, point positioning errors can be ignored.

Such type of instrument has to be used for measurement of Reference Parcels to be then reported in the LPIS.

D. When to perform parcel area measurement?

It is reminded that, where the information on the parcel's boundaries in LPIS and/or in the GSAA reflects the field reality, no area measurement is needed. The declared area will be considered as determined.

E. Determination of the parcel area, use of the technical tolerance

If a measurement is done, a tolerance can be applied in most cases to take into account the uncertainty of the tool used.

If such, then where the absolute (unsigned) difference between the measured and declared area is greater than the technical tolerance (expressed as an area in hectares to two decimal places), the actual area measured through physical measurement will be considered determined.

In the alternative case i.e. when the declared area is within technical tolerance of the measured area (below reported as the confidence interval) the area declared will be considered as determined.

*As from 2015, a **unique buffer tolerance** of maximum 1.25 m shall be used for area measurement related to agricultural parcels. This area tolerance is calculated by multiplying the parcel outer perimeter by the unique buffer tolerance value.*

F. Minimum size

The minimum parcel size applicable in a Member State has to be checked. Parcels found below this minimum parcel size are not eligible for aid and should be flagged with an appropriate code.

G. Parcel area measurement in the frame of "greening"

Information provided so far remain valid for parcel area measurement to be performed in the frame of crop diversification and also for EFA crop like features (i.e. nitrogen fixing crops, catch crops).

These **rules do not apply for all other area measurements to be done in the frame of EFA** (landscape features). For such areas, please refer to the technical specification provided in the Technical Guidance document on the On-The-Spot Check of Ecological Focus Areas requirements (DS-CDP-2015-09-FINAL).

H. Afforested areas - area measurements

Several of the rural development support measures are based on area, and a few of these concern afforested areas. These may be the case for first afforestation of non-agricultural land, Natura 2000 payments, and forest-environment payments.

Since measuring in afforested areas is in general difficult (with GNSS due to the risk of signal loss, on ortho imagery because parcel boundaries may not be visible), MS are encouraged to look for individual solutions adapted to their landscape, LPIS reference system and available data (number of claims, existence of professional survey tools). Validation tests of GNSS equipment (with adapted settings) may also be carried out. In such situation, MS may define appropriate tolerances, which shall in no case be greater than twice the tolerances set for parcel area measurements for OTS checks in first pillar. This means that MS may use a buffer tolerance of maximum 2.5 m applied to the perimeter of the parcel, with an absolute maximum of 2.0 ha.

I. Area measurement of permanent crops

Apart from specific support for the vineyard sector (e.g. restructuring), permanent crop parcels are part of the BPS/SAPS scheme and thus standard eligibility and area measurement rules apply.

Limits and eligibility of areas in a permanent crop parcel will be determined according to evidence of management as permanent crop as a homogenous unit of land.

For the details of specific support of the vineyard sector, please see the Guidelines for the implementation of certain provisions of Commission Delegated Regulation (EU) 2016/1149 and Implementing Regulation (EU) 2016/1150 of 15 April 2016 on the National Support Programmes in the Wine Sector. For the area measurements, the recommendations given in the Guidelines for measuring the area of vineyard parcels in the context of Regulations (EC) No 479/2008 and 555/2008 still apply (JRC technical note - EUR 23524 EN – 2008).

J. Diagnosis and codes for area measurement check

At the end of the OTS check process (i.e. after the pre-CAPI check, the CAPI or RFV), each claimed parcel should be assigned at least one code concerning the area and a retained area.

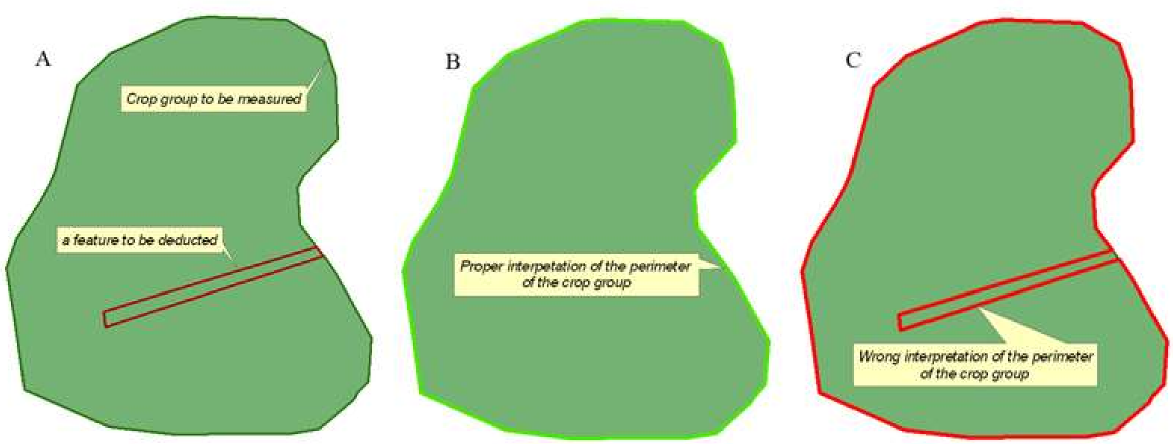
The roles of the technical codes are the following:

- Trace the work of the operator (e.g. for quality control purposes);
- Allow to determine the retained area for each claimed parcel;
- Describe the possibly area error found;
- Allow a posteriori analysis and identification of particular problems (e.g. high occurrence of a given code in a region).

When the area measurement is done, the comparison is done with the declared area taking into account the defined single buffer tolerance. In cases where the agricultural parcel is composed of several cadastral parcels, computing the tolerance at the level of internal cadastral parcel would lead to the application of an excessive technical tolerance.

Therefore, the single buffer tolerance has to be applied on the perimeter of the agriculture parcel only or on the external perimeter of contiguous agricultural parcels.

Area measurements always have to be done to limit the artificial elongation of parcel perimeter. See following illustration.



A series of "standard" codes have been defined in relation to specific conditions. Codes have been defined together with diagnosis of land use / cover aspects. For the details on codes, please refer to the dedicated chapter in land use / land cover checks.

K. Capping to the reference area

As a general rule the area(s) retained for the Basic Payment Scheme (BPS, SAPS) should not exceed the maximum eligible area of the corresponding LPIS reference parcel.

A similar cap applies in the case of a reference parcel containing several agricultural parcels. In particular, when these parcels are declared by different farmers, a proportional reduction of the retained areas may be applied. In any case, the contractor has to refer to the instructions of the national Addendum.

Finally, if the LPIS reference parcel contains several crops eligible for different area-related aid schemes, capping to the LPIS area applies individually for each scheme. If the LPIS reference parcel contain different type of agriculture area arable land, permanent grassland and permanent crop – the associated spatial information recorded in the LPIS, should be taken into account.

6.2 Land use / land cover check

The purpose of on-the-spot checks linked to land use / land cover will consist in checking at least:

- the declared land use or land cover to the extent requested by the regulation (BPS, SAPS, Greening, VCS, Rural Development support …);
- the number and/or position of landscape features where necessary;
- the respect of the cross compliance requirements and particularly of the Good Agricultural and Environmental Conditions (GAECs).

A. Classical field visit

Field inspection should be undertaken by operators having a very good knowledge and specifically trained in eligibility rules, cross compliance rules, and crop identification. Indeed, the check, for instance, of compliance of mixture of crop species in catch crop parcels may require very good competence in plant identification and taxonomy.

Field visits should be made at the best possible timing for identifying the crop(s), assessing its extent and/or assessing the quality management of the parcel.

Field visit documents such as maps for the overall location of the parcels and detailed location documents (e.g. parcel boundaries overlaid on a VHR image) should be in possession of the controller. Alternatively, navigation systems based on GNSS and systems allowing the display of images, vectors and data on a mobile computer in the field are highly recommended.

It is recommended to take digital photographs of the parcels visited and especially for parcels with problems, and store them in a database. Each photo should come with its geo-location, a parcel identification number, date and time of the image shooting, identifier of the operator. These pictures may be presented to the applicant or an auditor in a follow-up meeting, thus reducing the number of follow up field inspections to a minimum.

Finally, predefined codes should be used to report on the actual land use/land cover and any anomaly found.

B. Use of ortho-rectified imagery (CwRS)

Land use / land cover aspects may be checked by Computer Aided Photo Interpretation (CAPI) of current year imagery often supported by the use of automatic classification (supervised or unsupervised).

The CAPI of agricultural parcels will normally be carried out using at least one very high resolution (VHR) image (satellite ortho-image or aerial ortho-photo with a pixel size <0.75m (in some cases, like for the check of EFA landscape features pixel size <=0.50m)) of the current year. In addition to the VHR image, multi-temporal high resolution images may be provided upon detailed justification by the administration. It is also recommended to use the Copernicus Sentinel 1/2 sensors whenever suitable.

Depending on the agricultural land characteristics, staff availability, importance of the different schemes, some Member States may opt for a CwRS method based on the use of one VHR imagery to perform area measurements checks. Then, all checks concerning land use / land cover aspects will be done through Systematic Rapid Field Visits.

In the former SPS/SAPS CAP rules, the need to identify individual crop types was not very strong. With the entry into force of the 'greening' and especially the crop diversification requirements, there is a need to identify crops at parcel level (as it was the case during the 'couple payments' CAP period i.e. 1992-2004).

Methodology

The interpreter's work can be summarized as follows:

- detect non-eligible features (water, building, forest) paying attention also to features put in the 'negative list' in the considered Member States;
- pay special attention to trees on arable land (100 trees/ha eligibility criteria);
- check the crops subjected to coupled payments;
- where the Administration has decided to use remote sensing for the control of the GAECs, all declared parcels of the holding should be inspected;
- where the Administration has decided to use remote sensing for the control of 2^{nd} pillar (land cover related Agri Environmental Measures), all parcels under contract should be inspected.

We remind that interpreters should be specifically trained for checking all schemes related elements to be checked through imagery. They should be provided with common OTS checks guidelines.

During the photo-interpretation stage the interpreter must be able to simultaneously display several images (e.g. a VHR ortho-imagery and a multi-temporal suite of HR orthoimages) and also the vector and alphanumeric data for each application. They should have the possibility to display on-screen examples of parcels for which a preliminary ground survey has been done, and ground truth is collected..

> *The classical false colour composite (near-infrared, red, green) is in general sufficient for checking the crops/uses that need to be discriminated. However, in case images with more than 3 bands are provided, it is advisable to select and use different band combinations depending on the features or crops under inspection. The band combination usually includes the near-infrared one, the mid (or short-wave) infrared and one of the visible bands. The use of multi-temporal indices (e.g. NDVI image) is another option providing useful ancillary information.*

In case the crop check is supported by an automatic classification, it is recommended to never use the result of classification 'blindly' and always have a step of visual inspection of all parcels to confirm the diagnosis. When classifications are used, the classification process should be documented and detailed quality control records should be provided. Explanation should be given on how the classification results are used in the parcel categorisation (e.g. as an ancillary image layer helping the interpreter or as automatic parcel flagging).

BPS/SAPS land use / land cover check

In practice, land use check for BPS/SAPS will consist in checking compliance of the parcel with eligibility conditions. In essence, the CAPI work will mainly consist in focusing on the identification of non-eligible land (built up zones, rocks, transport network, 'negative list'). Interpreters should be trained in detecting these elements. It may also be of help to use classification algorithms for the detection of these crops or land covers. Although parcels not claimed will have no impact on the diagnosis, checking these parcels allows to better check claimed parcels (in case parcels not claimed share a reference parcel with claimed parcels) and to train the interpreter on specific crops (e.g. crops that may not be eligible for BPS/SAPS).

Check of Cross Compliance

Remote sensing data may be used in two ways for the control of cross compliance:

- Use of RS for a partial control of the GAEC.

- Use of RS as a support for the selection of the cross compliance sample (risk analysis).

Imagery use as a partial control of cross compliance:

Some GAEC (or SMR) may be checked on satellite or airborne imagery. This is the case for instance for the maintenance of a soil cover during winter, the prohibition of burning cereals stubble, or the maintenance of some landscape features. According to the minimum requirement defined for a given act or standard, MS may decide to use RS images to check specific conditions (e.g. requirements that need to be checked during autumn or winter).

In practice, during the photo-interpretation of the satellite imagery the CAPI operator will flag any case of possible non-compliance (e.g. doubtful land use) with an appropriate code.

In addition, cases of non-compliance in respect of some GAEC that would be observed during a RFV should be reported to the Administration.

Imagery use as a support for selecting the cross compliance sample:

On the CwRS OTSC sample or on the whole area covered by Sentinel HR images, an automatic classification (refined by CAPI) could provide a list of parcels potentially in breach with some GAEC. The corresponding dossiers may hence be part of the risk based sample for the controls of cross compliance of a given control body (the "1% sample" per competent authority).

Administrations should clearly describe the option(s) retained (no control of cross compliance with RS, use of RS for partial control or for risk analysis) for each of the control zones. If relevant, the GAECs to be checked and the criteria to be assessed should also be described as well as the specific imagery / processing requested (e.g. RADAR imagery in winter for the detection of bare soil).

Voluntary Coupled Scheme check

Methodologies to identify crops under VCS scheme are the same as the ones needed in the frame of crop identification to check compliance with the 'diversification' requirements. So for this section please refer to the 'crop diversification OTSC technical guidance' (DS-CDP-2015-08–FINAL).

Check of diversification

For this section please refer to the dedicated 'crop diversification OTSC technical guidance' (DS-CDP-2015-08–FINAL).

Check of Ecological Focus Areas

For this section please refer to the dedicated 'Technical guidance for the On-The-Spot check of Ecological Focus Areas (EFA) requirements' (DS-CDP-2015-09–FINAL).

Use of the monitoring system to complement CAPI work

As from 2017, the working document DS/CDP/2017/03 revising Reg. 2014/809 introduces the possibility to substitute OTSC by a system of monitoring.

This system is mainly based on the use of free Sentinel 1 and 2 satellites imagery.

Time-series processing as the ones used in the frame of monitoring can be used to provide additional information for the diagnosis of land use/land cover at parcel level.

For technical guidance concerning the monitoring system, please refer to the discussion document on the introduction of monitoring to substitute OTSC (DS-CDP-2017-03)

C. Codes for diagnosis

In classical Control with Remote Sensing (CwRS), i.e. control performed mainly in the office, diagnostic rules are applied at parcel, group and dossier levels. The objective of these rules is to separate the dossiers that will need a field visit from those which are considered as correct and therefore do not need any follow-up action (for the points that could be checked by remote sensing).

Several codes may be used simultaneously. When several codes are assigned to a parcel, the retained area and land use should correspond to the least favourable condition.

Some codes are likely to change after a rapid field visit. In the latter case, it is recommended to keep track of the two successive situations: i.e. to keep the code(s) before and code(s) after the rapid field visit.

In the frame of the control of cross-compliance, specific codes should be applied to flag parcels for which a breach to a specific GAEC or cross compliance issue is observed or suspected during the CAPI process.

In the frame of control of greening conditions, specific codes should also be applied.

A series of 'standard' codes have been defined and classified in three categories (see table below):

- The **T**x codes are assigned during CAPI to parcels not checked for some technical reason beyond the interpreter's control (e.g. parcel outside the image). As assigning a T code implies giving the benefit of doubt to the applicant, these codes should not be assigned to parcels deemed doubtful during CAPI.
- The **A**x codes correspond to anomalies, in particular those related to eligibility, and lead to the rejection of part or a totality of the parcel.
- The **C**x codes are assigned to the interpreted parcels (i.e. checked parcels) but for which the declared area (or crop) is not accepted by the interpreter. Different rules apply for computing the retained area.

If relevant, several codes could be assigned to the same parcel.

If both the declared area and the declared 'land use/land cover' under inspection are accepted, the controlled parcel will be coded as "OK".

Additional codes may be defined by the National Administration to record specific cases not described by existing codes (e.g. LPIS boundary to be updated, or codes for other schemes). In order to avoid confusion it is preferable:

- not to reuse already existing codes (by changing their definition);
- to create new codes by subdividing existing codes: for example A31 (unknown cadastral reference), A32 (valid cadastral reference, but no vector).

Moreover, the new code(s) should be connected to an existing category (T, A, C) as much as possible.

Calculation of retained area:

The last column of table below indicates which area should be retained at parcel level and therefore transferred to the crop scheme (group) level.

Table of standardstandard codes related to the CAPI conditions encountered at the parcel level, and proposed rules for the calculation of retained area

Observations at the parcel level	**Code**	**Areas transferred to the crop group**
Parcel outside all current year images Parcel outside the control zone Parcel covered by clouds, haze, snow, or flood (G[4]CAP 'meteo' flag)	**T2** **T3** **T4**	Use the declared area and land use
Parcel declared or found as less than the minimum parcel size set by the Administration	**A1**	Give zero value to the area
Parcel (or part) claimed more than once	**A2**	Give zero value to (the disputed part of) the area
Parcel or reference not found in the LPIS Area ineligible	**A3** **A4**	Give zero value to area
Parcel ineligible for SPS or SAPS	**C1**	Give zero value to the eligible area, except for "obvious errors". If possible, indicate the land use found
Parcel declared in one sub-group of crop scheme, but found in another (area correct)	**C2**	Use declared area and observed land use

Land use/cover correct, but area outside tolerance (over-declaration i.e. declared > measured)	**C3+**	Use measured area And observed land use
Land use/cover correct, but area outside tolerance (under-declaration)	**C3-**	
Land use interpretation impossible or parcel limit problem not resolved on the image	**C4**	Give zero value to the area
Obvious error not covered by another code	**E1**	Use measured area And observed land use
Land use/cover correct, area within tolerance	**OK**	Use declared area and declared land use

D. Rapid field visits

Rapid Field Visits (RFV) are directed to problem or doubtful parcels identified during the CAPI. Thus, they will be intended to check the land use / land cover and possibly some cross compliance issues (GAECs) in the field without contacting the farmer. Results of the RFV should be used for completion of the diagnosis at parcel level. Detail description of the possible RFV workflow is given in the technical guidance of the LPIS quality Assessment.

It is advised to take digital photographs of the parcels visited and stored in a database with their location, to be presented to the applicant in any possible follow-up meeting, thus reducing the number of follow up field inspections to a minimum.

Field visit documents such as maps for the overall location of the parcels and detailed location documents (e.g. parcel boundaries overlaid on a VHR image) will have to be provided to the staff in charge of RFV. Alternatively, navigation systems based on GNSS and systems allowing the display of images, vectors and data on a mobile computer in the field may be used. Predefined codes should be used to report on the actual land use and any anomaly found.

Finally, results of RFV may be used to assess the quality of the CAPI diagnosis work. Thus, the diagnoses established before and after RFV should be recorded.

E. Alternative solutions to evidence Land use/land cover

Out of the RFVs, Member State Administrations may use alternative solutions or data capture tools in order to conclude diagnoses on the parcels under check.

Drones (RPAS, UAV)

Unmanned aerial vehicles (UAVs) or Remotely Piloted Aircraft Systems (RPAS) better known as drones offer low-cost aerial VHR camera platforms. These devices allow very fast VHR image data capturing and tools for ortho-rectification processing are available on the market. Products are thus easy to integrate in the

IACS-GIS. While having a limited capacity of area coverage (some km2), they offer the possibility to be operational on demand within few hours. They could be used, in absence of satellite imagery, to acquire images to check the presence of catch crops in a small region or to check the presence of winter cover. It can be also a useful solution to check parcels that would be difficult to access on the ground (e.g. in semi-mountainous areas, swampy areas …).

Geotagged photos

Geotagging is the process of adding and embedding geographical information, and possibly additional temporal and/or textual information into the metadata file of a photograph. The location and time of acquisition will be obtained through the GNSS antenna of the photo camera or smartphone.

Member State Administrations should strongly consider the utility of this low-cost, readily available, and easy to use technology. They could integrate, in their IACS, geo-tagged photos provided by farmers as evidence of compliance to specific conditions or rules. For instance, a farmer could send a geo-tagged photo of his Durum wheat field(s) being part of a Voluntary Couple Support. Also, a geo-tagged photo could be sent of a grassland just mowed to show compliance with a mowing date imposed by the legislation. The provision of such geo-tagged information will avoid the field visit that otherwise would be necessary.

Today, different devices offer the possibility to capture geotagged photos such as **digital camera, smartphones, tablet PCs or even GNSS devices**.

a) The **minimum information**

The minimum information to be embedded or stored, for each image taken, should consist of:

- Its **date and time** of capture;
- Its **geographical location**;
- Its **orientation (image heading)**;;
- The identification of the **operator**;
- Information on the **device**.
- It is also recommended to register the **elevation** and the Dilution Of Precision (**DOP**). This last parameter gives a qualitative indication on the positional precision.

- The date and time

The date and time of photo capture should be registered directly through a **GNSS antenna** (internal, external) of the device.

Manual geotagging, by setting date and time directly through the device menu, should be **prohibited** as it introduces possibilities of error or manipulations.

Even if embedded in the metadata file, it is advised to also automatically stamp the date and time on the photo.

Example of automatic encryption of date and time in a photography

- The geographical location

As for the date and time, the location (longitude, latitude coordinates) of photo capture should be registered directly through a **GNSS antenna** of the device.

It is possible to enter directly the coordinates in the device or by selecting a location from a map using software tools, but this **manual geotagging** should also be **prohibited.**

It is reminded that the antenna of the device gives the position. For device with external antenna, instruction must be given to place it close to the camera lens.

It is also important to stay still some seconds on the viewpoint before taking the picture.

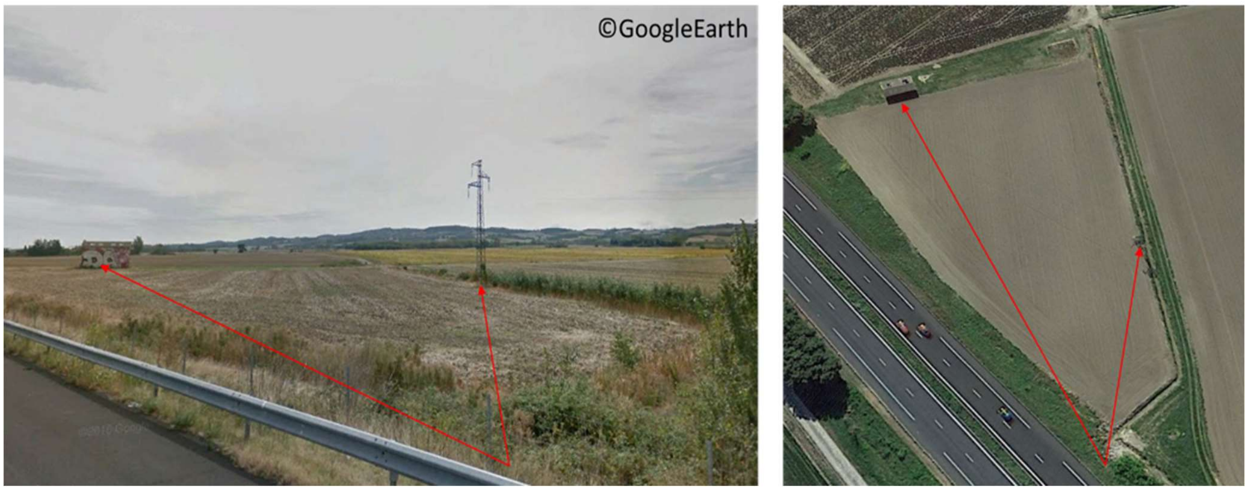
Currently, internal antennas of smartphones, tablet PCs, digital cameras provide a positional accuracy of some 10 to 20 meters. It is important to reduce this uncertainty to a meter, sub-meter one. This may be achieved indirectly by taking the picture close to the border of the parcel and **identifiable landmark** (e.g. a corner of the parcel see example hereafter).

Photo with identifiable landmark allowing to ensure its correct location

While not yet available, there is a fast developing technology, which very soon should provide solutions to improve the positioning accuracy. One can site among others: EGNOS compatible smartphones, low-cost sub-meter accuracy external antenna, or even smartphones with dual frequency GNSS receivers.

- The orientation

In addition to the location, it is important to ensure that the operator was pointing at the right targeted parcel. Thus, information on the **direction** (heading) the camera was pointing must be collected. This could be obtained directly from a compass system embedded in the device but most of current ones are vitiated by a +/- 10 degrees deviation. As alternative solution, and if existing, the operator should point the camera toward a feature/ a landscape element that could be easily depicted afterwards on orthophotomaps (see example below);



Example of photo containing elements allowing determining the direction the camera was pointing when shooting the photo.

Some applets using **augmented reality technology** are also now available. It allows superimposing the limits of the reference or agricultural parcel of concern, live on the screen view. The photo orientation is deducible from this overlay.

- Identification of the operator

A procedure should exist to **identify the operator** (in most of cases a farmer) providing the photo. This can be obtained using a system of authentication through personal login and password prior to upload a photo in a dedicated database.

- Information on the device

As part as the information needed for any possible check of the photo content integrity, as a minimum the type of camera model and the focal length should be registered.

b) The **image format and quality**

Today the main image file formats are JPEG or JPG files (Joint Photographic Experts Group), TIFF or TIF (Tagged Image File Format) and RAW.

JPEG is the far more common file format for photos and often the only format available in digital cameras. However, with JPG format, the image is compressed when recorded. This may induce loss of image details if the compression level is too high. So, devices should be set to '**Low compression JPG**' or 'fine' format to limit distortions (even if photo size will be bigger).

One has to note that most recent cameras allow creating and recording a RAW image and a JPEG image at the same time (**RAW+JPG**). This setting maybe suitable to **limit** possibilities of image **manipulation**. However, since no compression is done on RAW images, their size will often be 2 to 3 times bigger than the JPG equivalent ones. In most areas in Europe, internet and/or GSM bandwidths will be too coarse to allow transferring these RAW format images.

The **camera resolution** should be **at least of 5 million pixels**. This size consents to display and possibly magnify the view without becoming too blurry or "grainy" thus allowing to identify features in the picture.

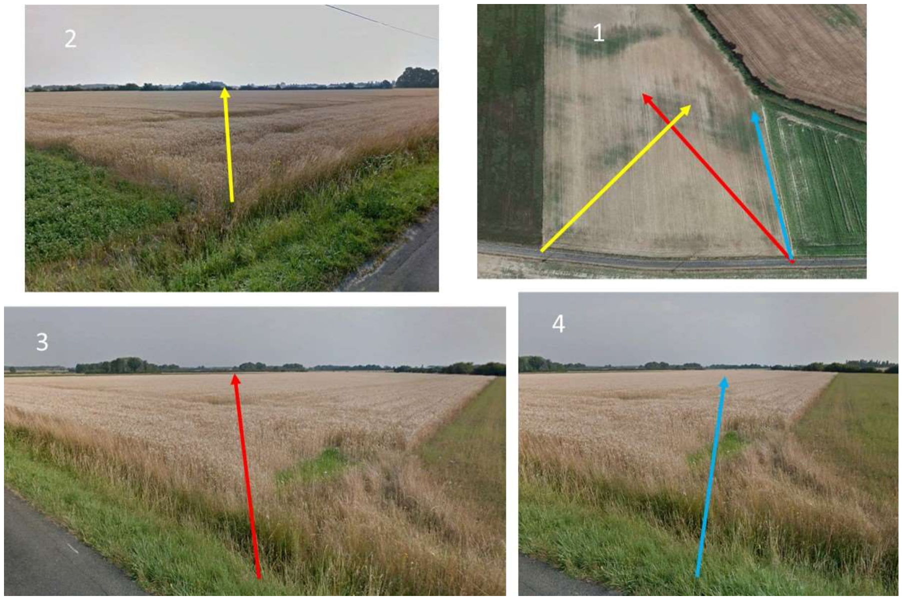
Instruction should be given to ensure a **good exposure** of photos (e.g. not facing the sun, no dark conditions …) to obtain usable and exploitable images.

Last but not least, attention should be paid to some **privacy aspects**. As example, no people or car plate should be visible in imageson image captured.

c) The **minimum number and type of photo**

The number and type of photos (e.g. general view, "macro" …) will depend on the land use/land cover or any other element that need to be provided as evidence.

Nevertheless, it is recommended to provide at least 2 photos of the element taken from different viewpoints or view angle (as exemplified hereafter). Photos taken from 2 different viewpoints allow to have a rather comprehensive view of the element. Photos taken from same viewpoint but with 2 different view angles allow to limit the possibility of image manipulation.



Parcel in image 1 seen from 2 viewpoints (2 and 3) and 2 view angles (3 and4)

Sometimes, a “**macro**” photo will be needed as evidence (e.g. presence of Durum wheat for VCS, mixture of crop as EFA cover crop…). Another photo should be captured from the same viewpoint, with the camera pointing higher at the horizon showing the corresponding field.

One should note also that many devices present now the possibility to capture **360 degrees** or **panoramic** photos. In some circumstances, this type of format may represent the optimal evidencing option.

d) **Information integrity and security**

Administrations should develop a standard operating procedure to ensure the information integrity and security of geo-tagged photos transfer; in other words, ensure that the whole information content has, in no manner, been falsified.

Some administrations have already developed dedicated smartphone/tablet applets to be used by farmers (or by inspectors) using combinations of solutions to avert tampering with data. As example, a photo is blocked for upload if not sent within few seconds after capture (in case a GSM network is available for transfer at the location of picture capture). Alternatively, a code is encrypted in the photo at capture and its integrity checked at administration’s database entry.

Also, over the last decades, standard detecting image manipulation techniques have been developed that are based on pixel, format, physical or geometrical processing (so-called forensic analysis).

Geo-tagged images should be **stored** in their **original file formats**. It means that no additional compression process other than the one done at data capture (JEPG) should be performed since critical image information may be lost and artefacts introduced.

Files should also be stored as **'read-only'** to avoid modifications or deletions. **Any viewing** and/or manipulation of photos should be done on a **copy** of the original one.

Other ancillary digital information

Some current legal requirements may prove to be very difficult to check using satellite imagery or even in the field like the check of presence of Durum wheat as part of Voluntary Coupled Support or the check of a cover crop mixture as part of the EFA greening scheme.

Member State administration may consider the use of ancillary information to be sent by farmers like a scan or a digital photo of the tags bags or invoice of purchased seeds. Having these document geotagged will not bring useful information. It is however more important to ensure that the name of th farmer, the date of the invoice and the quantity of seeds appear on the invoice.

F. Categorisation at scheme group level

For each scheme group, the total declared area of the crop group (Dg) will be compared to the total retained area of the crop group (Mg). In practice, the areas declared and retained for all parcels claimed in a given scheme group are summed, therefore allowing compensation between over-claimed and under-claimed parcels of the same scheme group (if this compensation is allowed in the Member State concerned).

Sorting of scheme groups into 'Accepted' and 'Rejected'

For a given scheme group, the following three cases may be encountered:

- A1: The declared area is equal to the retained area (Dg - Mg = 0).
- A2: The declared area is less than the retained area (Dg - Mg < 0). In this case, the Administration will accept and pay only the claimed group area.
- R: The declared area is greater than the retained area (Dg - Mg > 0).

The first two categories are considered as accepted. All scheme groups with a declared area greater than the retained area (third category) shall be rejected.

Sorting of rejected scheme groups into minor and major rejects

As any rejected scheme group should be subjected to a follow-up action, since it incurs reductions or sanctions, a second test may be performed in order to sort minor and major rejects. This test, which consists in comparing the discrepancy (Dg - Mg) with some threshold to be fixed by the Member State, is useful when the follow-up action varies according to the discrepancy.

As per default threshold value, (Dg - Mg) > 3% Mg or 2 ha can be suggested. If higher than the threshold, the scheme group is classified as RMa (major rejection) if not it is classified as RMi (minor rejection).

Obviously, if the follow-up action is the same for all rejects (e.g. letter sent to the farmer and field inspection in case of no reply within a number of days), sorting the rejected scheme groups appears as unnecessary.

The follow up actions for minor and major rejects are of the responsibility of the Administration. Attention has to be paid to establish a diagnosis for the BPS crop group, indicative diagnosis may have to be recomputed accounting for the payment entitlements before starting any follow-up action.

G. Categorisation at dossier level

There are three steps in the categorisation of the dossiers: A conformity test; a completeness test; and a final diagnosis per dossier combining the two previous ones.

Conformity test

A dossier is accepted if all crop groups are accepted (i.e. Dg-Mg <= 0 for any scheme group). The table below summarizes this test for Member States making a distinction between minor rejects (all crop groups are minor rejects) and major rejects (i.e. at least one crop group is a major reject) at dossier level. The proposed coding (DMi and DMa) remains valid whatever the test applied for sorting the rejected dossiers (e.g. fixed threshold in ha or monetary unit). If no sorting is applied (i.e. all rejected dossiers are processed in the same way), the categories DMi and DMa could be amalgamated into one category coded DR1.

For dossiers concerned by BPS scheme, the categorization (as Accept or Reject and for the Rejects, as minor or major Rejects) will be considered as provisory as long as the payment entitlements will not have been taken into account. This provisory categorization may be used as an indicator of the quality of the application.

Input	Test	Dossier conformity test	Dossier codes	
			Yes	No
The whole dossier	D1	All crop groups accepted (Dg-Mg <= 0)	DA1	-
		If at least 1 scheme group is rejected, dossier is rejected	DMi	DMa
		Are all rejected crop groups coded RMi ?	All rejected groups are RMi	at least 1 rejected group is RMa

Completeness test

The purpose of the completeness test is to avoid accepting a dossier which has been checked on a too restricted extent due to technical problems, i.e. T codes. In such a case, the dossier is considered as not having been controlled by remote sensing. If the dossier was part of the control sample, it has to be completed it in the field, i.e. field inspected.

A dossier will be categorized as "complete" if the percentage of parcels with T codes with respect to the claimed parcels is lower than 50% (Cf. Table below).

Input	Test	Dossier completeness test	Dossier codes	
			Pass (complete)	Fail (incomplete)
Area retained for: the whole dossier	D2	(# of parcels with T codes) / (# of claimed parcels) <= 50%	DC	DI

In order to improve the efficiency of the control, applications sharing a reference parcel with any application from the control sample may be included. This recommendation is valid for any type of OTS check (physical inspection or CwRS), and particularly for checking joint cultivations, but is probably easier to apply in CwRS than in physical inspection. Such 'ancillary' applications are likely to be incomplete and should hence not be completed in the field, in contrast with the applications from the control sample. However, although very partially checked, these applications could be rejected on the basis of irregularities found on the parcels checked.

H. Final diagnosis at the dossier level

The final diagnosis summarises the diagnoses of the conformity and completeness tests at dossier level. This table below proposes a general diagnostic code per dossier and describes a possible follow-up action to be undertaken for rejected crop groups or incomplete dossiers. It is reminded that incomplete dossiers that were part of the initial control sample have to be completed in the field. In some Member States, the contractor may be in charge of the RFV necessary to complete the dossier (Cf. National Addendum).

The general diagnostic code proposed takes account of the distinction between dossiers rejected for minor and major discrepancies. If such a sorting is not used, the diagnostic codes can be simplified (e.g. DR7 and DR8 for rejected complete and rejected incomplete respectively).

Whatever the diagnosis at dossier level, Member States may decide to manage parcels outside tolerances by appropriate administrative procedures, in particular if the anomaly originates from the LPIS.

A dossier categorized as incomplete will be counted and paid to the contractor if it has been processed and photo-interpreted normally. It neither will be counted nor paid if it appeared incomplete before the digitization and the photo-interpretation.

Test	Conformity	Completeness	Code	Conclusion
D5	Pass	Pass (complete)	DA5	Dossier accepted by remote sensing
D6	Pass	Fail (incomplete)	DI6	Dossier not controlled with Remote Sensing; the parcels which have caused the dossier to be incomplete are verified in the field
D7	Fail due to small discrepancy only (DMi)	Pass (complete)	DR7p	Dossier 'rejected'; all the rejected crop groups being RMi, an appropriate administrative procedure may be used to notify the farmer of the correction
D8	Fail due to small discrepancy only (DMi)	Fail (incomplete)	DR8p	Dossier 'rejected'; the parcels that caused the dossier to be incomplete are verified in the field; the opportunity can be taken to check rejected scheme groups (in case no appropriate administrative procedure has been applied)
D7	Fail due to large discrepancy (DMa)	Pass (complete)	DR7f	Dossier 'rejected'; an appropriate administrative procedure may be used to notify the farmer of the correction, but usually the rejected crop groups are verified in the field
D8	Fail due to large discrepancy (DMa)	Fail (incomplete)	DR8f	Dossier 'rejected'; both the rejected scheme groups and the parcels that caused the dossier to be incomplete are verified in the field

6.3 Production of OTSC report

Although there is no OTSC report template currently provided by the Commission, Article 41 of Regulation (EU) No 809/2014 lays down the mandatory elements of the OTSC report. Accordingly, it is recommended to develop and use a common digital control report. This digital form should contain predefined lists of required information.

In addition to the elements foreseen in the above-cited Article, it is preferable that the report contains at least:

- Names of person(s) conducting the inspection;
- Date of inspection;
- Measurement tool used along with its specific settings (e.g. GNSS measurement in vertex or continuous mode, scale of CAPI digitalization);

- Detailed summary of inspection findings (parcels okay, parcels flagged or rejected, documentation and codes for the rejection, screen shot and/or field photograph of the problem found, geo location of the parcels, possible follow-up action)
- Document all parcels for which an LPIS concern has been identified and for which a follow should up be done by the competent LPIS custodian;
- Document all parcels for which an EFA concern has been identified and for which a follow should be done by the competent EFA layer custodian;
- …

For all information that is considered as mandatory (e.g. inspector name) it is advised to prevent the form from closing as long as these fields remain unfilled.

- Sign and certify each inspection report.

Each inspection report must be signed and certified by the permittee to be considered complete. Where inspections are carried out by a contractor or subcontractor, it is recommended to also have the form signed and certified by the inspector, in addition to the signature and certification required of the permitted operator. The template report should include a signature block for both the administration and the farmer.

Copies of all inspection reports with all records must be retained for at least 10 years.

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7 Analysis of the campaign – Act for the next campaign

In this section, some statistical procedures and other good practices are suggested in order to take the best advantage of the control results and thus to prepare the next campaign year in the optimal conditions.

7.1 Quality Controls

It is important to implement a quality management in all OTSC procedures. This quality control process be can performed internally and/or targeted to the contractor. Any contractor is required to carry out an internal quality assurance which will result in quality control records. These records should be kept for inspection by the administration.

It is advised to perform an independent external quality control. This was formerly carried out by the Commission on one control zone per contractor. As from 2009, the JRC stopped this regular check of all contractors.

However, after the entry into force of the new CAP rules and on specific request by a MS's Administration, the JRC can provide support and carry on a QC process.

To do this, the MS Administration has to prepare and provide a set of data (i.e. LPIS and interpreted vectors, orthorectified imagery, orthorectification Quality Control Records (QCRs), declaration data, measured and retained areas at parcel level) corresponding to one CwRS zone.

Ideally, the quality controls should be spread on the whole CwRS zones. This would also enable to check the consistency and homogeneity of the controls over the country/region.

As a general rule, it is also recommended to verify in the field a minimum number of the accepted dossiers from a selected control zone. As dubious dossiers are consistently checked in field, it is considered that there is no need to check them again during the QC.

For each control zone, the number of dossiers to be verified and the quality acceptance threshold (i.e. maximum number of dossiers with initial diagnosis not confirmed) are determined by the standard ISO 2859-1:1999 (AQL set to 1,5% with a simple sampling plan and normal inspection).

Total number of OTSC dossiers on a considered zone	Number of dossiers to select	Number of dossier diagnosis discrepancy accepted
2-8	2	0
9-15	3	0
16-25	5	0
26-50	8	0
51-90	13	0
91-150	20	1
151-280	32	1
281-500	50	2
501-1200	80	3
1201-3200	125	5
3201-10000	200	7
10001-35000	315	10

In practice, and using the last line of the above table as example, for a Paying Agency that had between 10000 and 35000 dossiers as part of the OTSC, 315 dossiers should be randomly selected. These dossiers will be (re)checked to see how many dossiers will have their initial diagnosis confirmed or on the contrary contradicted. At the end of this QC, if not more than 10 dossiers have their initial diagnosis disapproved, the process of OTSC is to be considered as efficient and reliable (statistically significant).

If not proven efficient, at the end of this QC procedure, any inconsistency should be documented and the causes of such discrepancy should be identified (e.g. lack of training, tiredness of the inspector, workload …) in order to take action to improve the OTSC processes and methods.

The quality control should be carried out to assess also the suitability of CwRS for checking the GAECs, CD and EFAs requirements (and possibly SMRs related to environment) that the MS have decided to check with RS. In particular, during the inspection of the farms belonging to the GAEC sample, it is recommended to perform rapid field visits on a sample of OK parcels in order to ensure that no anomaly was overlooked by CwRS.

In addition, the Member States have the responsibility to carry out an external quality control of the contractor's work.

7.2 Study of residual errors

The error rates are computed as the ratio of area not found on area declared. As those error rates are computed on a sample and not on the whole population, they must be considered as an estimator of the true error rate of the population. Thus, MS are recommended to analyse those results, taking the expected variability of this estimator into account. It is considered not sufficient to verify numerically that the estimated error rate is below some threshold (2% is typically the accepted limit). A proper statistical test may be set out to address the question "Is this error rate smaller than the 2% limit?". Similarly, when comparing two error rates, their respective uncertainties may be taken into account in a test "Is the error rate A smaller than the error rate B?".

In this regard, the standard deviation(s) of the error rate(s) can also be estimated based on the sample(s). The formula for this estimation generally depends on the sample design(s). Specific formulas are detailed in Annex 3 as a recommended means of analysis.

The exhaustive control of a zone (e.g. by CwRS) is a particular case because it is actually a control of the whole population over that zone. Consequently, the error rate computed on this particular zone is the exact error rate over that zone (i.e. there is no uncertainty and the corresponding standard deviation is equal to zero). Obviously, in this context, since this error rate is an exact value, it can directly be compared to any fixed threshold. However, a control zone remains a subset of the population so the error rate that is found over that zone is merely an estimator of the error rate of the population (i.e. general case as above).

For instance, if the value found after an exhaustive control of a zone is equal to 1.75%, it is sure that the error rate of the zone is smaller than 2% (i.e. no test needed). But the value 1.75% is an estimator of the true error rate over the whole population and its standard deviation needs to be computed in order to assess whether it is statistically smaller than the 2% limit (see the details in Annex 3).

7.3 Analysis of campaign

Information gathered though the campaign and especially based on the number of errors revealed or not revealed, taking into account the quality control phase should help administrations to reflect upon the setting of the OTSC methodology(ies) through:

- Considering the appropriateness of the various control methods applied in respect of the particularities to be controlled;
- Considering the links of the different elements within IACS (GSAA, administrative checks, OTS Checks, sampling, number and type of errors, pre-established information etc…);
- The appraisal of efficiency of the control methods: imagery and/or field;
- Detailed study of photo-interpretation and automatic classification processes; software and personnel, photo-interpretation keys;
- Analysis of the geometric and radiometric corrections of imagery;
- Analysis of the imagery use (usefulness of images ordered, relevance of acquisition windows, % of RFV on total parcels photo-interpreted …);
- Analysis of measurements made with other tools (mainly GNSS devices);
- Analysis of the working timetable and "bottlenecks";
  If relevant, analysis of share of work between administration and contractor partners; Estimate of the total number of dossiers processed each day;
- usefulness of ground data collection;
- …

'Lessons learnt' should also be combined with the outcomes of the LPIS Quality Assessment.

It is advised to formalise these findings producing an assessment report.

Then, from the analyses above, it is also advised to produce a remedial action plan or textual description of remedial actions to be implemented for the following OTSC campaign.

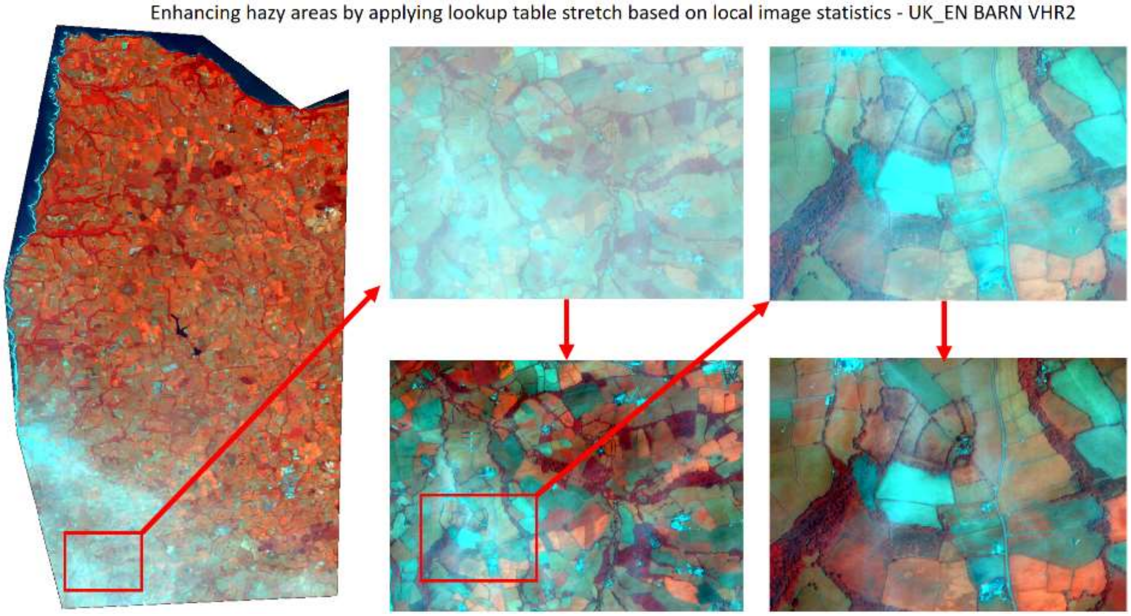
End of main document

8 Annex 1: Details of image radiometric correction

Overall clipping of histogram

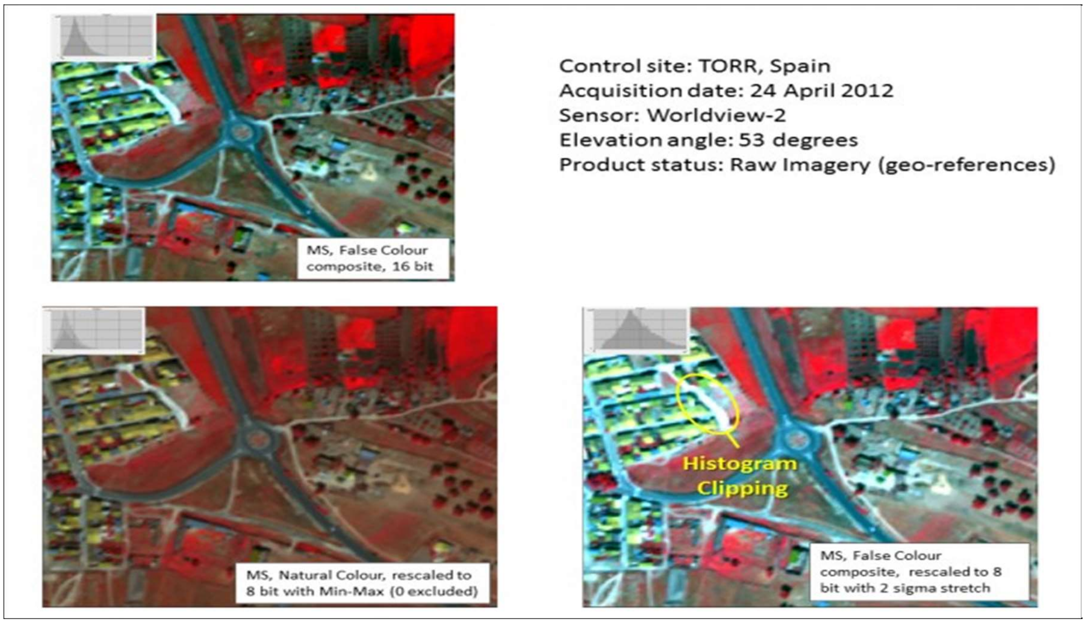
Controlling that the available dynamic range is efficiently used with no undesirable saturation helps considerably for the preservation of the original information content needed for the correct manual photointerpretation (CAPI). It is especially helpful to improve readability of the image over dark or bright areas (caused by shadows or highly reflective objects).

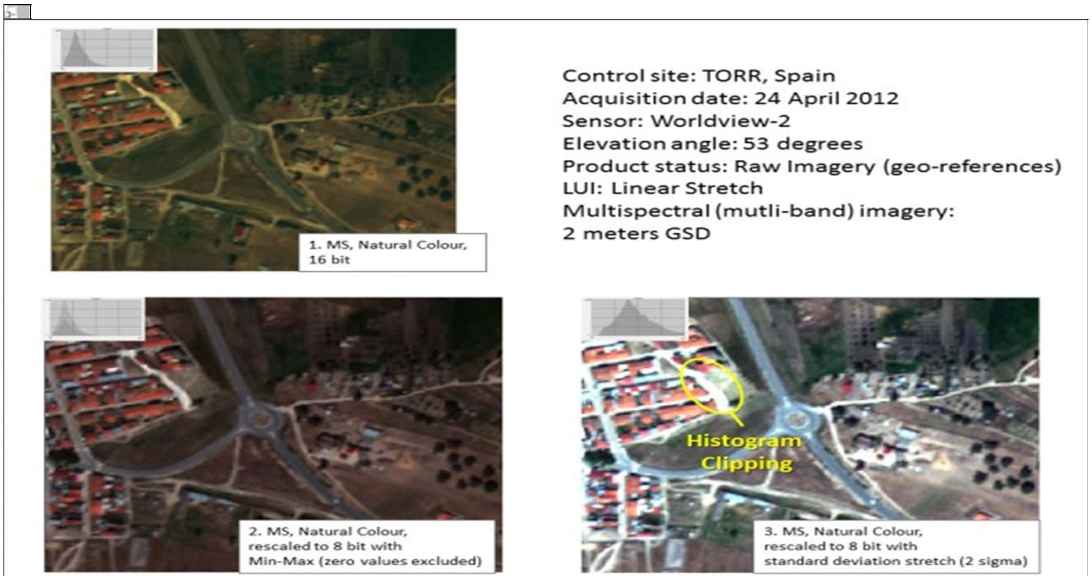
Enhancing hazy areas by applying lookup table stretch based on local image statistics - UK_EN BARN VHR2



The calculation of this metric is straightforward, monitoring whether the rate of pixels belonging to the first and last 5 bins of the luminosity histogram are each less than 0.5% of the total (recommended). In addition, it might be worthwhile to also apply this radiometric 'clipping' metric separately for each individual channel (MS and PAN), in the case a VHR bundle ortho-product is used. This is especially valid for the NIR band, since it is a key contributor for the false-color composite. This NIR does not contribute to the luminosity value, and is therefore not assessed by default. Checking the NIR band 'cut-off' of the VHR satellite sensors is important as we sometimes observe an over-exposure (saturation) of the grey values for the NIR band over smooth surfaces with high reflectance (partly due to specular effect). More often, such cutting off can also be a result of the rescaling to 8 bit (see images below). By processing with 16-bit files, you maintain all the information necessary to ensure quality in all portions of the histogram.

So, the best practice in imagery use is to maintain its greater bit-depth.





Histogram peak

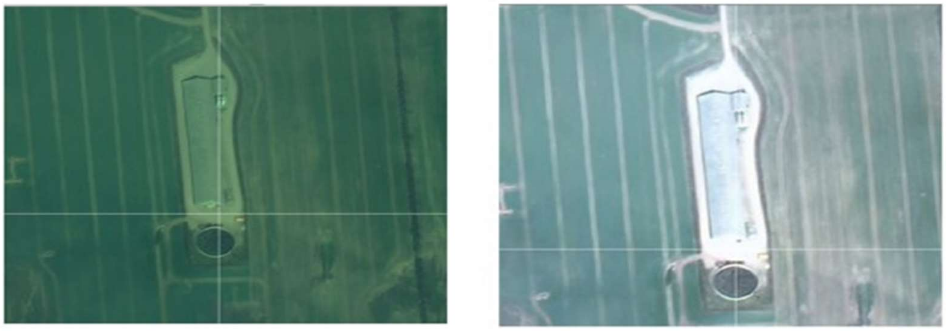


Image with preserved radiometric information

Image with reduced radiometric information due to histogram clipping

The aim of this parameter is to ensure that the overall lightness of the image is optimised. It controls whether the minimum and maximum extents of the histogram peaks of the different spectral bands are within the recommended +/- 15% range from the median value (it is 128 for 8 bit range). Indeed the exact placement and shape of the histogram can vary significantly depending of the image content (important factors are lighting conditions, land cover type, topography, etc.). Therefore, the recommended thresholds cannot be considered as absolute requirements. The aim is not to force the histogram to fit on or converge over a common spot. We could rather apply a shaping function or specific LUT (look-up table) stretch to achieve more balanced visual appearance on screen. Although dedicated to the MS part of the orthoimagery, this metric might be relevant also for the PAN band as well.

Colour balance

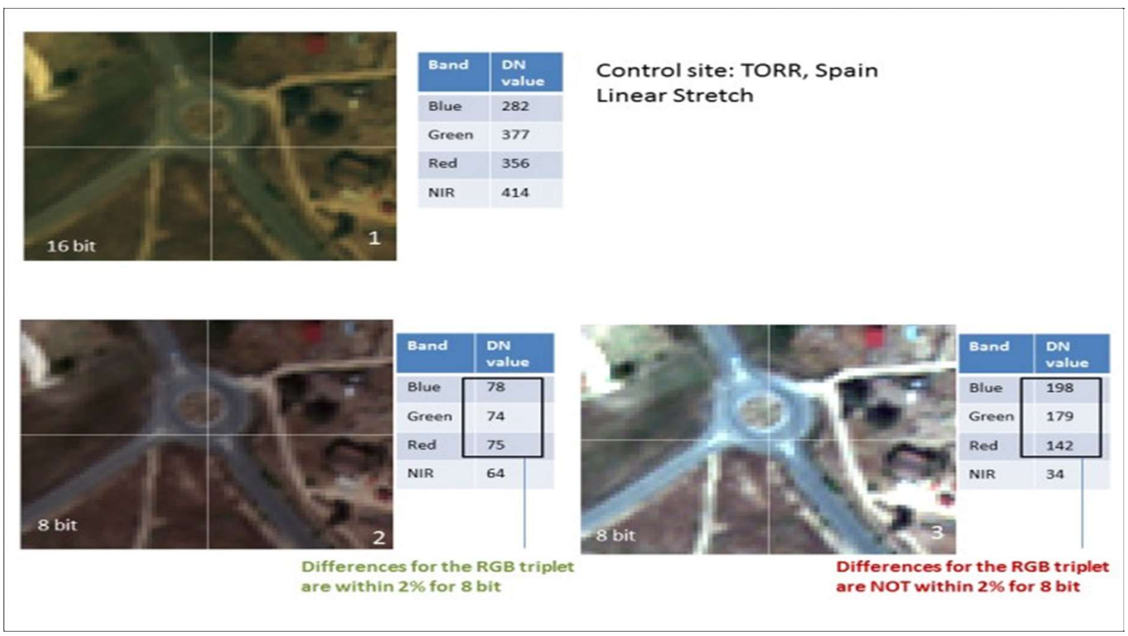
The purpose of this parameter is somehow similar to the previous one. It provides a simple quantitative method for assessing whether the tonal neutrality over the orthoimage is met. It can be argued whether or not such numeric verification is needed, since the qualitative visual check often provides good estimates. The problem is that this visual check is made against reference data, which is often not available, or (if present) is not always reliable. In addition, qualitative color balance evaluation is performed only under proper lighting conditions on display systems that are calibrated and have the correct tone scale workstation conditions that cannot be always fulfilled. The proposed metric checks whether the difference between the minimum and maximum digital counts of the RGB pixel values of a given triplet is less than the recommended 2% of the total available bit range (5 bins for an 8 bit image). Even if the metric is very simple to apply, there are certain issues with respect to its representativeness:

The first issue is that the chosen triplet should belong to a spectrally neutral object, such as paved roads or building roofs. The results highly depend on the quality and representativeness of the sample selected. In principle, we expect a neutral object to have the same reflectance intensity along the visible wavelength range, resulting in rather achromatic (grey) colour appearance. However, a reliable visual assessment of such neutrality could be jeopardised by the same negative factors that have impact on the qualitative visual assessment (lighting conditions, calibrated monitor, etc.).

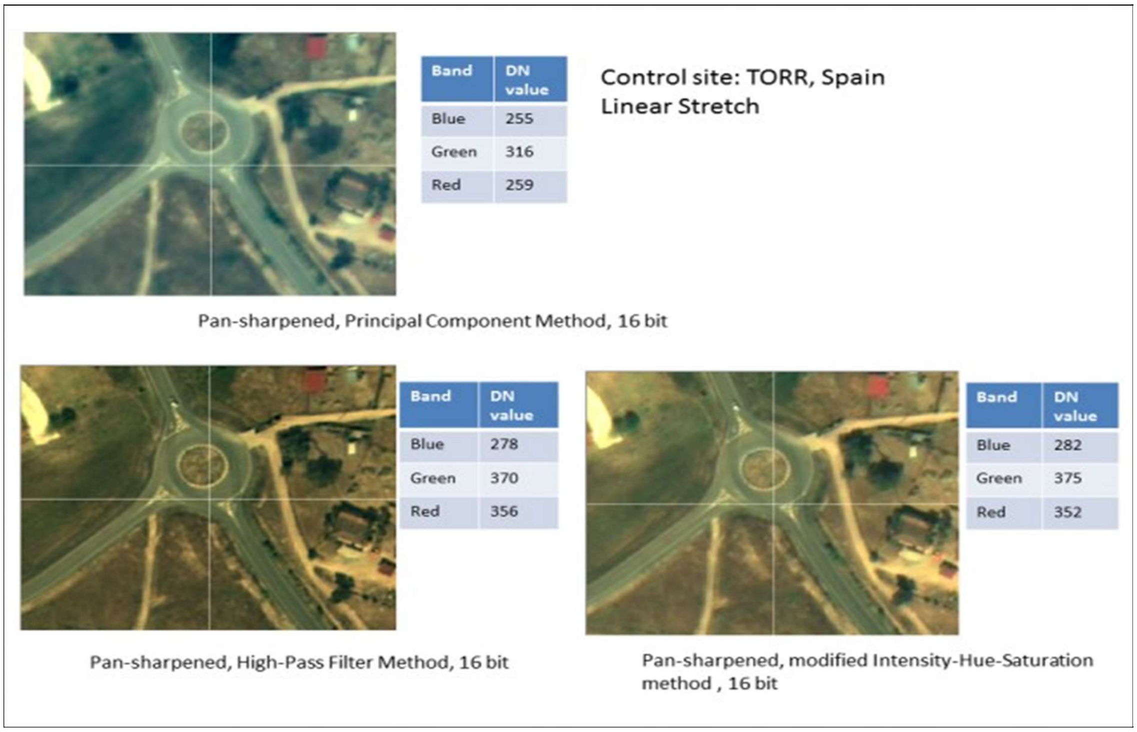
The second issue is that the metric is based on measuring the colour balance on, albeit well-representative, still isolated spots of the image. It would make sense also to check the homogeneity of the object where the triplet is located. The ITT report for NAIP specifies a different metric and threshold for the difference between triplets across an image, within the same object type or cover type (see page 23 of the report). In addition, the report suggests also another metric controlling the colour saturation that is consistently applied on the whole image (see point 4.3 on page 14). Further research is needed to reveal which metric is more relevant in the context of LPIS and CwRS.

Finally, we need to be aware that for VHR satellite data the degree of colour preservation the original MS image depends considerably on the rescaling and pan-sharpening methods. Often the appropriate sharpness of the PAN is achieved at the expense of poorer colour recovery or vice-versa.

On picture below, you can see a 16bit image (1), rescaled to 8-bit with Min-Max method (2) and with StDev method (3). Differences for the RGB triplet are within 2% for (2), but not for (3).



The picture below shows the same image pan-sharpened with 3 different algorithms and showing RGB values for the same triplet. We can see the DN values inside the RGB triplet vary depending on the pan-sharpening method.



Noise

Noise is defined as non-image related variations in intensity and can have an effect on the interpretation of an image. The Signal to Noise Ratio (SNR) method proposed in the JRC ortho-guidelines are based on the simple ratio between the mean DN value and the standard deviation of the DN values over a given uniform neighbourhood (often calculated on the base of a 3X3 moving window). It should target areas that are prone to be noisier. The Rose criterion (after Albert Rose) states that an SNR of at least 5 is needed to be able to distinguish image features at 100% certainty (see the Rose Model). However, it is not yet clear whether this method of calculating the SNR is the optimal in the CAP context. The JRC ortho-guidelines propose that the standard deviation alone as a global statistic over the whole image gives sufficient estimate on the amount of undesirable noise. The recommended upper limit of the standard deviation is 12. Further analysis can be made in selected homogeneous/inhomogeneous areas. Some contractors propose as well the PSNR (Peak signal-to-noise ratio) as an alternative measure. Furthermore, we need also to take into account that the acquisition systems of VHR sensors and the new digital aerial cameras are designed and adjusted in a way to ensure that in the majority of cases, a sufficient ratio between the meaningful input signal and the background noise. In such case, the SNR metric should be probably focused on assessing the quality of the different image compression methods after the ortho production.

Contrast

Contrast is one of the basic and most essential metrics monitoring the amount of information that an image can provide. High contrast images allow better distinction of land cover feature and facilitate at great extent the work of the CAPI operator. The contrast in the JRC ortho-guidelines is expressed through the coefficient of variation, which is the standard deviation of the DN values as a percentage of the available grey levels. It should preferably be in the range of 10 % - 20%. It should be calculated separately for each band (MS and PAN), in case if VHR bundle ortho-product. The ITT report suggests also an alternative contrast metric (calculated on the luminosity) given in point 4.2 of the report. It derives the number of bins between the minimum and the maximum of the cumulative luminosity histogram function. In principle the modern digital sensors (aerial or satellite) with high radiometric resolution (11bit or more), do not experience problems providing images with sufficient contrast, since the adjustment of their dynamic range during the acquisition and pre-processing ensures that the full histogram extent is obtained for each channel, leaving some margins at the tail for further post-processing. However, the dynamic range of the input imagery depends not only on the light source intensity and target reflectivity, and can become an issue for imagery with noticeable percentage of cloud cover or haze.

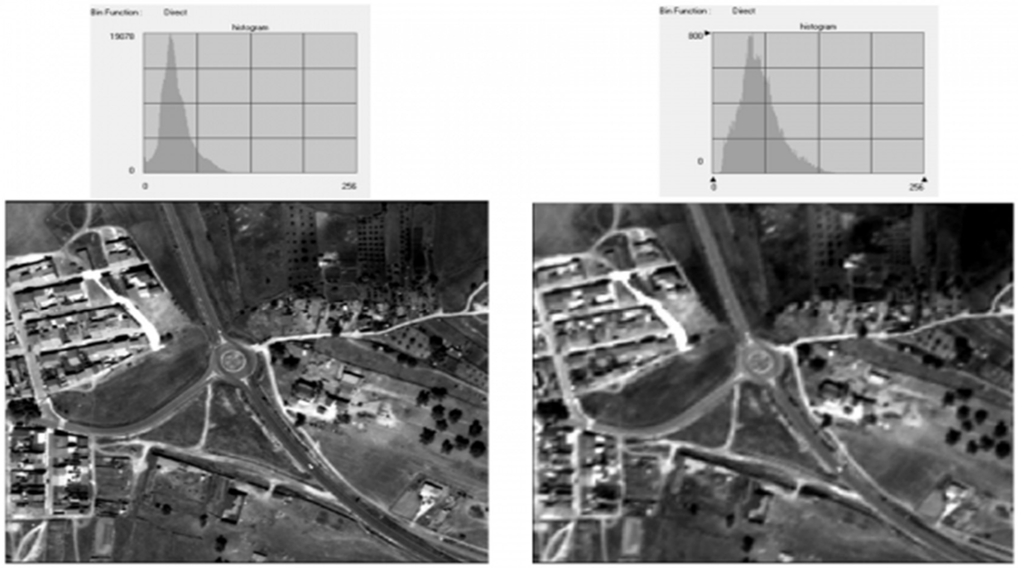
Luminance histogram

Luminance histograms are more accurate than RGB histograms at describing the perceived brightness distribution or "luminosity" within an image. Luminance takes into account the fact that the human eye is more sensitive to green light than red or blue light. The luminance histogram also matches the green histogram more than any other colour.

In order to produce a luminance histogram, each pixel is converted so that it represents a luminosity based on a weighted average of the three colours at that pixel. This weighting assumes that green represents 59% of the perceived luminosity, while the red and blue channels account for just 30% and 11%, respectively. Once all pixels have been converted into luminosity, a luminance histogram is produced by counting how many pixels are at each luminance, identically to how a histogram is produced for a single colour.

An important difference to take away from the above calculation is that while luminance histograms keep track of the location of each colour pixel, RGB histograms discard this information. A RGB histogram produces three independent histograms and then adds them together, irrespective of whether or not each colour came from the same pixel.

When assessing the luminance of VHR satellite data in particular, one should pay attention to the fact that the luminosity histograms generated for the original multispectral image and the resulting pan-sharpened product are different. This is mainly due to the "non-linear" contribution of the panchromatic component in the pan-sharpened product (see the example below)



Luminosity image created from Pan-sharpened image (Principal Component Method, 8 bit)

Luminosity image created from original multispectral image (natural colour, 8 bit)

9 Annex 2: JRC "Area measurement tool validation method"

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

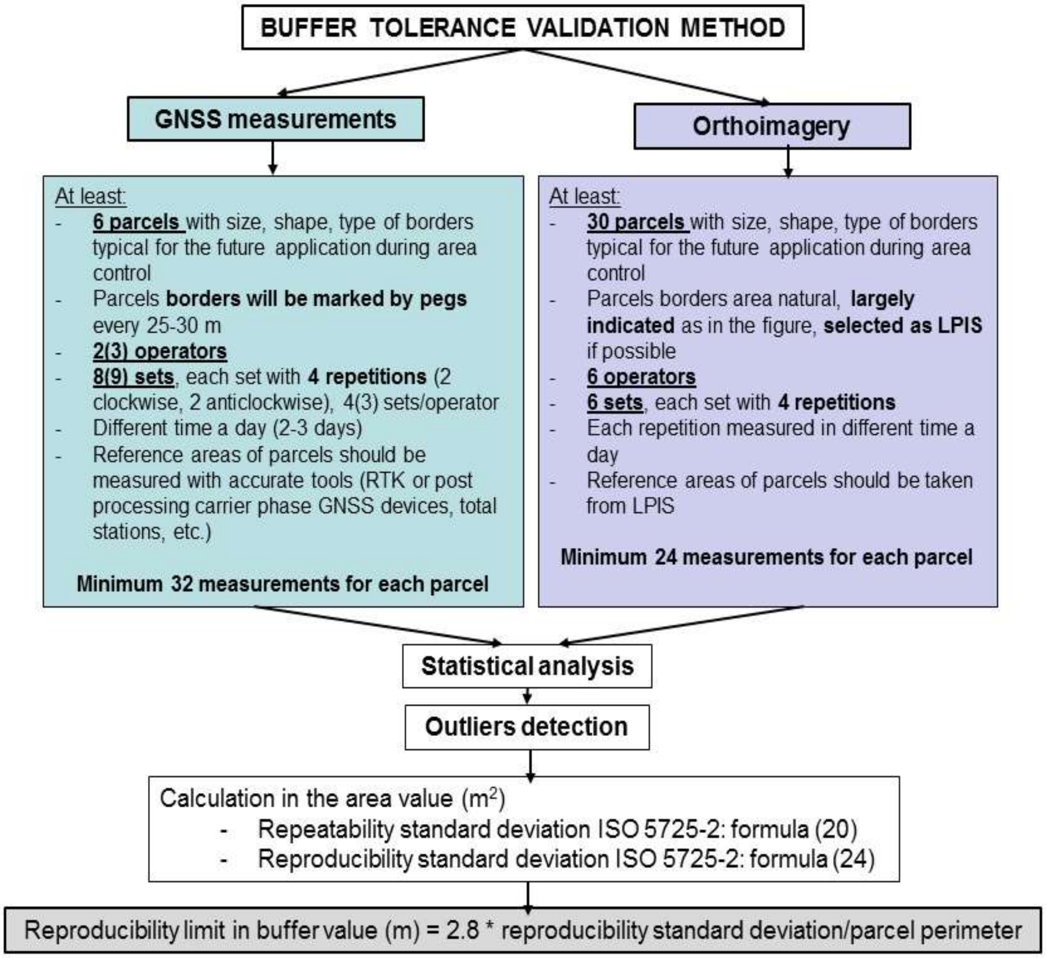
It should be set to limit as much as possible 'external' error factors (e.g. bad use of instrument, non-respect of parcel border …).

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
Orthoimagery
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
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 (m2)
- 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 document.*

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.

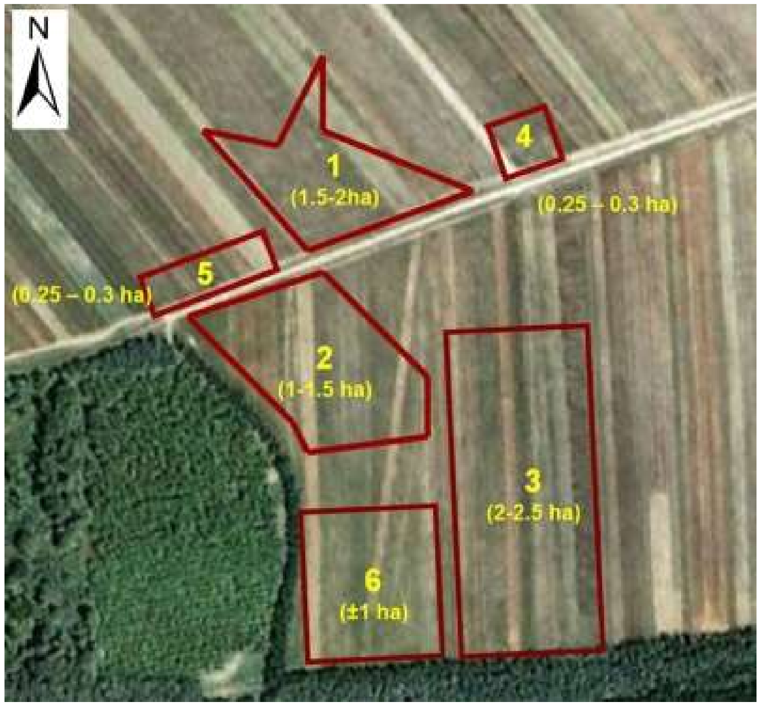
Shape

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 reference shapes 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

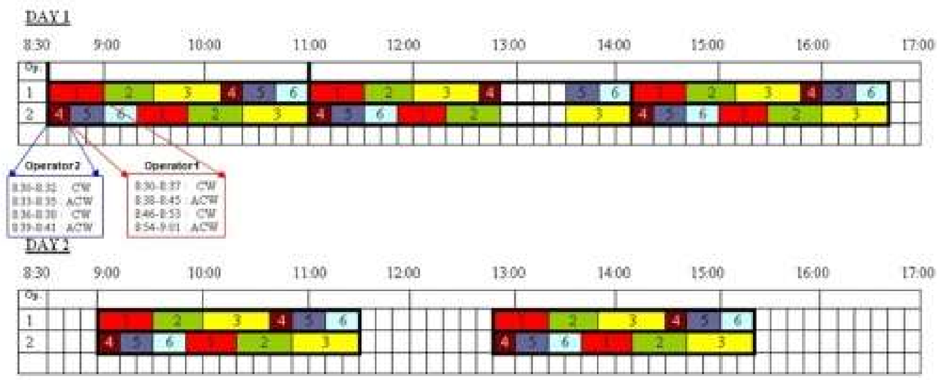
Standard deviation of measurement repetitions should be estimated ***against a reference area*** *of the considered parcel. The reference area of the test parcels should be established with a surveying tools or GNSS RTK measurements. It can also be taken from a LPIS reference area if a reference shape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



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):

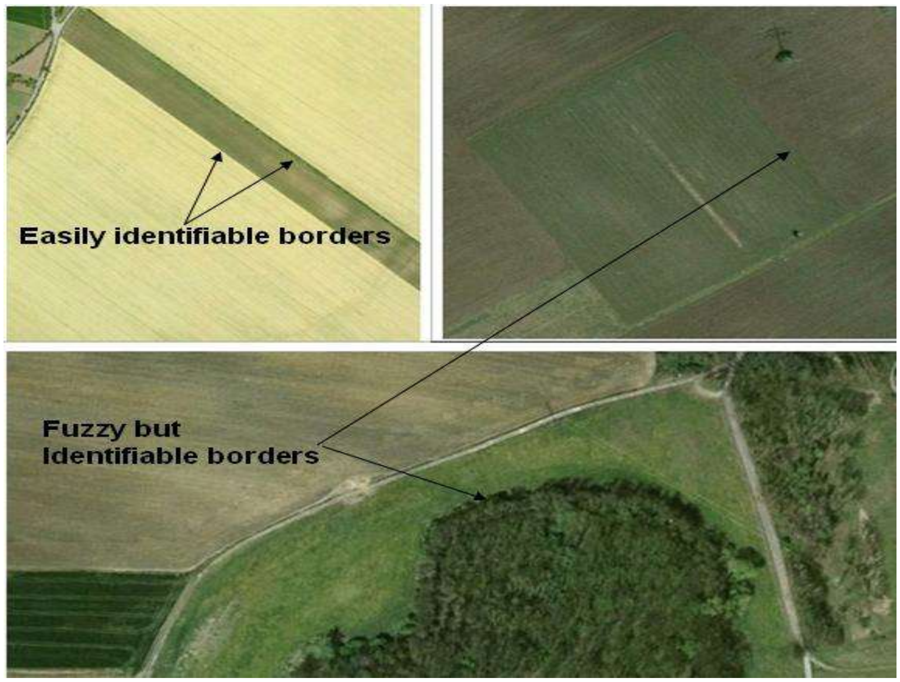
- good border: 15 parcels
    - S and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
    - M and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
    - L and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
- "fuzzy" border: 15 parcels
    - S and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
    - M and SF1/SF2/SF3 - 2/2/1 i.e 5 parcels
    - L and SF1/SF2/SF3 - 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’.



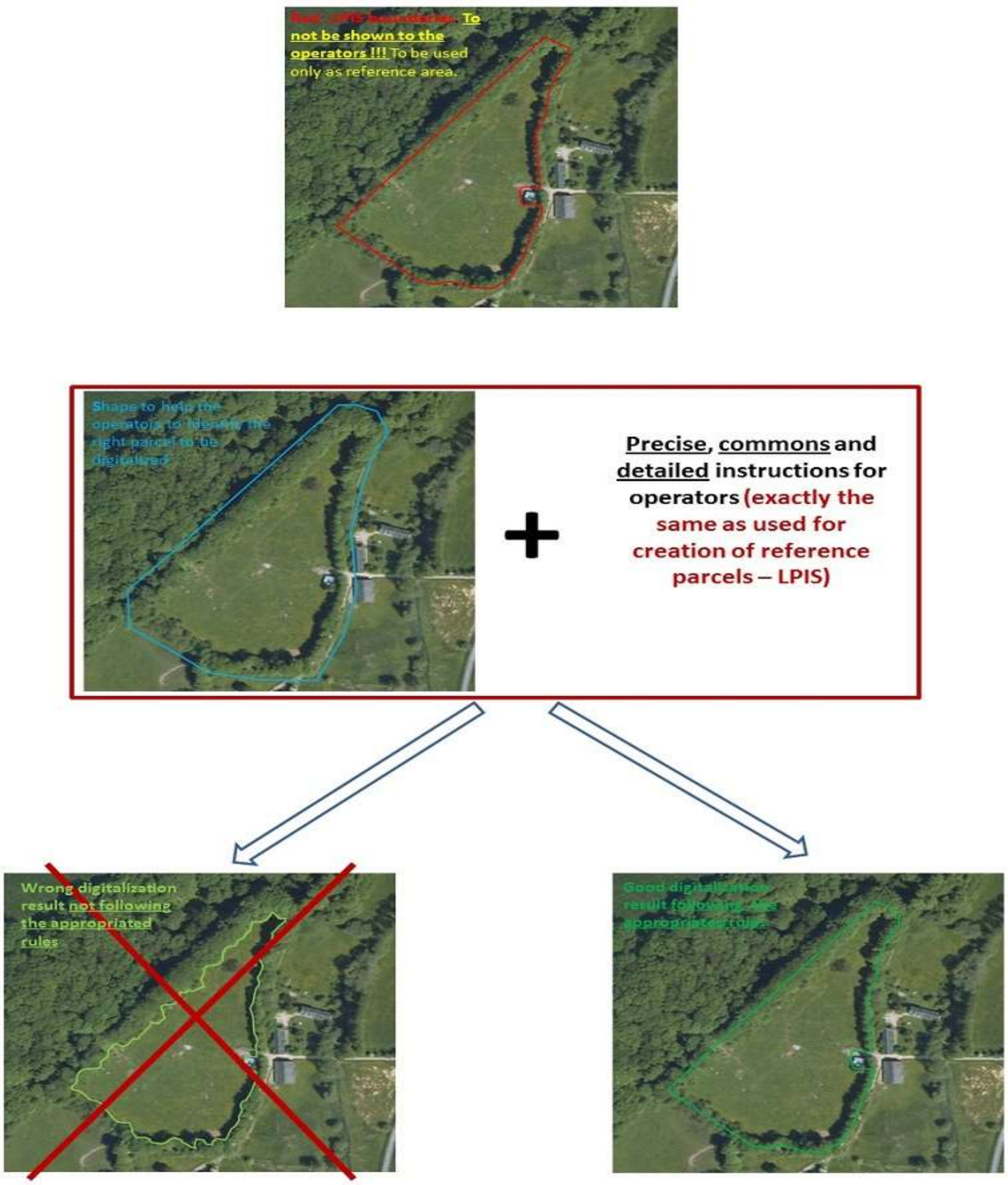
Examples of 'easy' and 'fuzzy' borders that should be part of the parcels sample

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.



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

Observation results (9 sets per parcel, 4 repetitions per set)

Operator - i	Lab - L	Repetition k	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

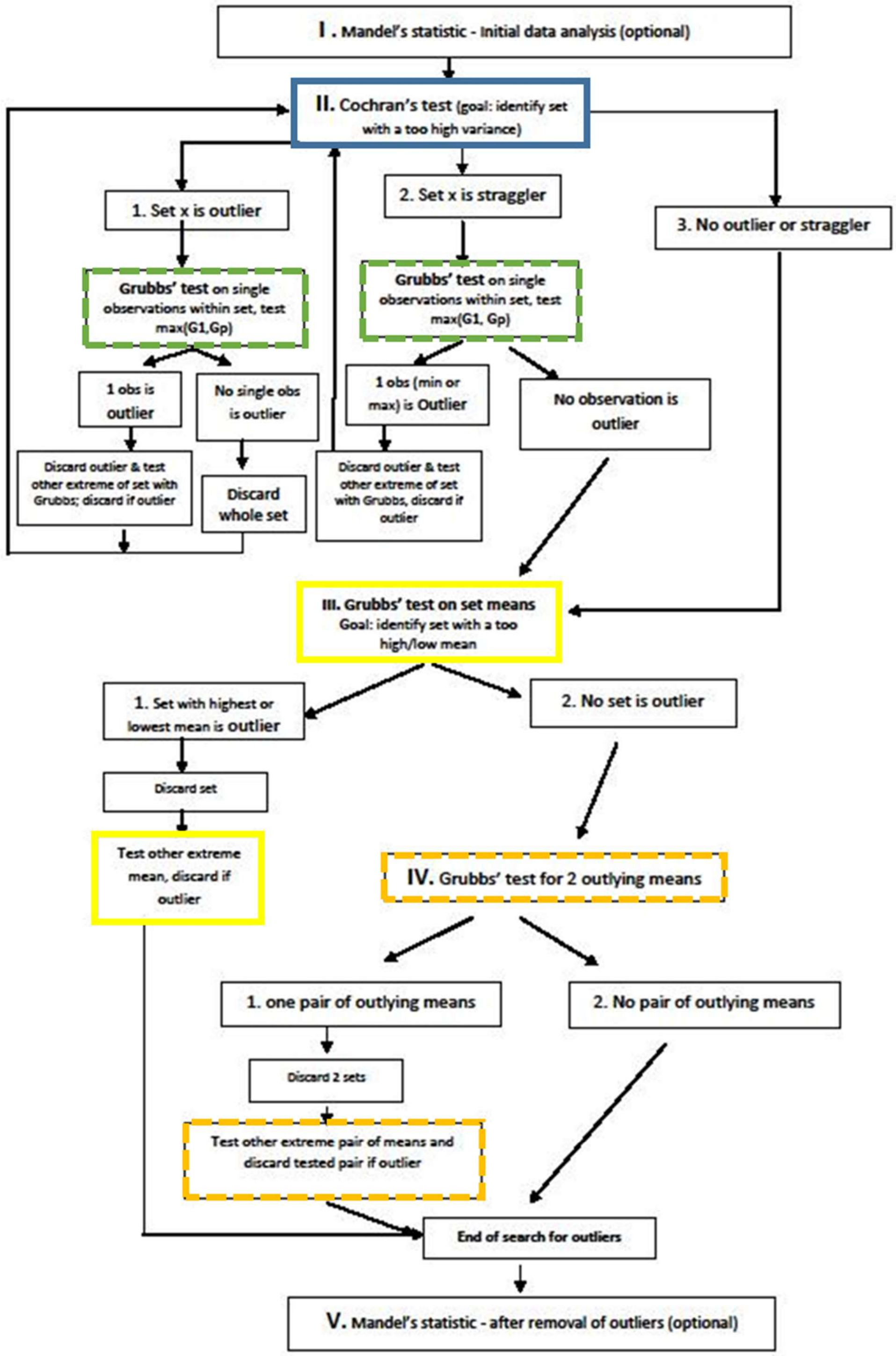
One should make sure to avoid rounding the values of the mean and standard deviation statistics. Slight differences can propagate and create numerical issues (e.g. negative value where a positive value is expected).

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.


I. Mandel's statistic - Initial data analysis (optional)
II. Cochran's test (goal: identify set with a too high variance)
1. Set x is outlier
2. Set x is straggler
3. No outlier or straggler
Grubbs' test on single observations within set, test max(G1,Gp)
Grubbs' test on single observations within set, test max(G1, Gp)
1 obs is outlier
No single obs is outlier
1 obs (min or max) is Outlier
No observation is outlier
Discard outlier & test other extreme of set with Grubbs; discard if outlier
Discard whole set
Discard outlier & test other extreme of set with Grubbs, discard if outlier
III. Grubbs' test on set means Goal: identify set with a too high/low mean
1. Set with highest or lowest mean is outlier
2. No set is outlier
Discard set
Test other extreme mean, discard if outlier
IV. Grubbs' test for 2 outlying means
1. one pair of outlying means
2. No pair of outlying means
Discard 2 sets
Test other extreme pair of means and discard tested pair if outlier
End of search for outliers
V. Mandel's statistic - after removal of outliers (optional)

Cochran's test statistic C

$$C = \frac{s_{max}^2}{\sum_{i=1}^{p} s_i^2}$$

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

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

and

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

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 s_{Lj}^2 is negative, it must be manually set to 0. In such case, $s_{rj}^2=s_{Rj}^2$.*

$$s_{rj}^2 = \frac{\sum_{i=1}^{p}(n_{ij}-1)s_{ij}^2}{\sum_{i=1}^{p}(n_{ij}-1)}$$

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

$$s_{Rj}^2 = s_{rj}^2 + s_{Lj}^2$$

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 s_{Lj}^2 are negative for the parcels E and F. One can see that in that case $s_{rj}^2=s_{Rj}^2$.

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.);
    - 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;
- Test data.

An example of xls file containing the collected data from an area measurement validation test can be found on WikiCAP

(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.

10 Annex 3: Recommended means of analysis of residual errors

A. Testing the significance of a random error rate on one control zone

For an individual error rate (i.e. the error rate of a single control zone or the error rate of the whole sample), the statistical test is rather simple. It is actually similar to the test that is performed for the LPIS Quality Element 1b within the LPIS QA exercise.

First, the standard deviation S_R of the error rate R must be estimated. This estimation depends on the type of sample, i.e., random or from the risk analysis and also on the group of beneficiaries that this sample represents (i.e. one control zone or the whole population of the MS).

If the error rate R is computed from a random sample, one must use the following procedure:

- For each individual dossier in the sample, compute the difference $q_i = E_i - R * C_i$ where $C_i$is the claimed area and $E_i$is the area not found;
- Compute S_q as the sample standard deviation of the vector of q_i;
- S_R is then computed as

$$S_R = \sqrt{\frac{N-n}{N-1}\frac{N * S_q}{n * TotC}}$$

where n is the number of dossiers in the sample, $TotC$ is the total claimed area over the considered zone (i.e. either the control zone or the full MS territory) and N is the total number of dossiers over the considered zone (again, either the control zone or the full MS territory).

If the error rate R is computed from a risk-based sample, the procedure for estimating the standard deviation of the error rate is more complex. It will be proposed in details with clear examples in the WikiCAP.

Once, the standard deviation S_R is estimated, one must evaluate the upper limit of error (ULE) with

$$ULE = R + t_{n-1,0.95} * S_R$$

Where $t_{n-1,0.95}$ is the quantile at 95% of the Student distribution with n-1 degree of freedom.

Finally, the conclusion of the test "Is the error rate *R* smaller than the 2% limit ?" depends on which of the following cases is verified:

Cases	Conclusions
$R < ULE \leq 2\%$	The error rate is significantly smaller than 2%.
$R \leq 2\% < ULE$	There is not enough evidence that the error rate is smaller than 2%.
$2\% < R < ULE$	There is enough evidence that the error rate is larger than 2%.

B. Comparing random error rates from different control zones

For the comparison of two error rates from independent samples (e.g. error rates from two different control zones, risk versus random samples), the preparation is the same. Only the test differs has it tries to address questions such as "Is the random error rate A larger than the random error rate B?" or "Are both random error rates equal?".

The random error rates R_A and R_B and their respective standard deviations S_A and S_B must be evaluated individually as described previously and accordingly to the type of samples.

The statistic of the test will be computed as

$$T = \frac{R_A - R_B}{\sqrt{S_A^2 + S_B^2}}$$

Then, according to the test that is considered, the conclusion of the test depends on which of the following cases is verified:

Tests	Cases	Conclusions
"Is R_A larger than R_B?"	$T \leq t_{m,0.95}$	There is not enough evidence that R_A is larger than R_B.
	$t_{m,0.95} < T$	R_A is significantly larger than R_B.
"Are R_A and R_B equal?"	$abs(T) \leq t_{m,0.975}$	There is not enough evidence that R_A and R_B are different.
	$t_{m,0.975} < abs(T)$	There is enough evidence that R_A and R_B are different.

where the value *m* is computed as

$$m = \frac{(S_A^2 + S_B^2)^2}{\frac{S_A^4}{n_A - 1} + \frac{S_B^4}{n_B - 1}}$$

$t_{m,0.95}$ *and* $t_{m,0.975}$ are respectively the quantile at 95% and 97.5% of the Student distribution with m degree of freedom and n_A and $n_B$are the sizes of the samples *A* and *B* respectively.

C. Comparing two error rates: paired case

For the comparison of two error rates from dependent sample (e.g. in case of reprocessed dossiers during a QC or for testing the equivalence of CwRS and classical checks), the procedure is slightly different. Instead of working on the error rates separately, one must keep the original structure of the sample, i.e. the sample is in fact constituted as pairs of observed area-not-found (e.g. a CAPI measurement and a field measurement) on the same dossier.

First, the standard deviation S_{RDif} of the difference of the error rates $R_{Dif} = R_1 - R_2$ must be estimated. This estimation depends on the type of sample, i.e., random or from the risk analysis.

If the error rate R_{Dif} is computed from a random sample, one must use the following procedure:

- For each individual dossier, compute the difference
  $q_i = (E_{1,i} - E_{2,i}) - (R_1 - R_2) * C_i$
  where C_i is the claimed area and $E_{1,i}$ is the area not found using the first method and $E_{2,i}$ is the area not found using the second method;
- Compute S_q as the sample standard deviation of the vector of q_i;
- S_{RDif} is then computed as

$$S_{RDif} = \sqrt{\frac{N-n}{N-1}}\frac{N * S_q}{n * TotC}$$

  where n is the number of dossiers in the sample, $TotC$ is the total claimed area over the considered zone (i.e. either the control zone or the full MS territory) and N is the total number of dossiers over the considered zone (again, either the control zone or the full MS territory).

If the error rate R_{Dif} is computed from a risk-based sample, the procedure for estimating the standard deviation of the error rate is more complex. It will be proposed in details with clear examples in the WikiCAP.

Once, the standard deviation S_{RDif} is estimated, one must evaluate the lower and upper limit of error (LLE and ULE) with

$$LLE = R_{Dif} - t_{n-2,0.975} S_{RDif}$$

$$ULE = R_{Dif} + t_{n-2,0.975} S_{RDif}$$

where $t_{n-2,0.975}$ is the quantile at 97.5% of the Student distribution with n-2 degree of freedom.

Note that there are n-2 degrees of freedom and not n-1 as in the test on one isolated error rate in previous section. Also, it is a two-sided test so there are two limits: LLE and ULE.

Finally, the conclusion of the test "Are the error rates R_1 and R_2 equal ?" depends on which of the following cases is verified:

Cases	Conclusions
$LLE \leq 0\% \leq ULE$	There is not enough evidence that the error rate are different.
Else	There is enough evidence that the error rate are different.

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