RSPO Guidance for Land Use Change Analysis

Revised version March 2017

Introduction

This guidance is prepared as a revision to the Land Use Change Analysis (LUCA) under RSPO Remediation and Compensation Procedures (RaCP) issued by the RSPO on 9th May 2014. The Compensation Task Force has revised the RaCP based on data and lessons learnt from the one year staged implementation period of 9th May 2014 to 9th May 2015.

This guidance will serve as an accompanying document to the RaCP procedures to help LUCA practitioners to complete the LUCA process and prepare the report. The LUCA should be implemented referring to the flowchart in **Figure 1**. To facilitate its use for work benchmark, this guidance is divided into sections that contain description of each stage on the flowchart. In addition, pre-LUCA (before the execution of the flowchart: to determine the assessment scope) and post-LUCA (after the execution of the flowchart: reporting) stages guidance is also added to this guidance.

1. Determining the Scope of the LUC Analysis

1.a. Area Scope

LUCA is carried out throughout the entire area within legal boundaries applicable at the time the company/management unit performed its land clearance without prior HCV assessment.[1] Therefore, the company must attach copies of all relevant licenses and permits of the operational area along with a copy of the original license maps issued by the Government [a]. This is to ensure that the entire license area is covered in the analysis.

1.b. Scope of Assessment Period and Cut-off Dates

The LUCA scope is divided into four periods, as follows:

(i) Period 1: Nov 2005-Nov 2007. The initial date is 1st November 2005 (as the baseline) [2] and the cut-off date is 31st November 2007. The cut-off date of Period 1 constitutes the initial date of Period 2.

(ii) Period 2: Dec 2007-Dec 2009. The initial date is 1st December 2007 and the cut-off date is 31st December 2009. The cut-off date of Period 2 constitutes the initial date of Period 3.

(iii) Period 3: 1st Jan 2010 [3] - 9th May 2014[4]. The initial date is 1st January 2010 and the cut-off date is 9th May 2014. The cut-off date of Period 3 constitutes the initial date of Period 4.

(iv) Period 4: the period after 9th May 2014. The initial date is 10th May 2014.

Note: For all four periods, the final cut-off date is immediately after the finalization of the HCV assessment (*see* paragraph ii below).

[a] in the format of .shp and .pdf or .jpg files

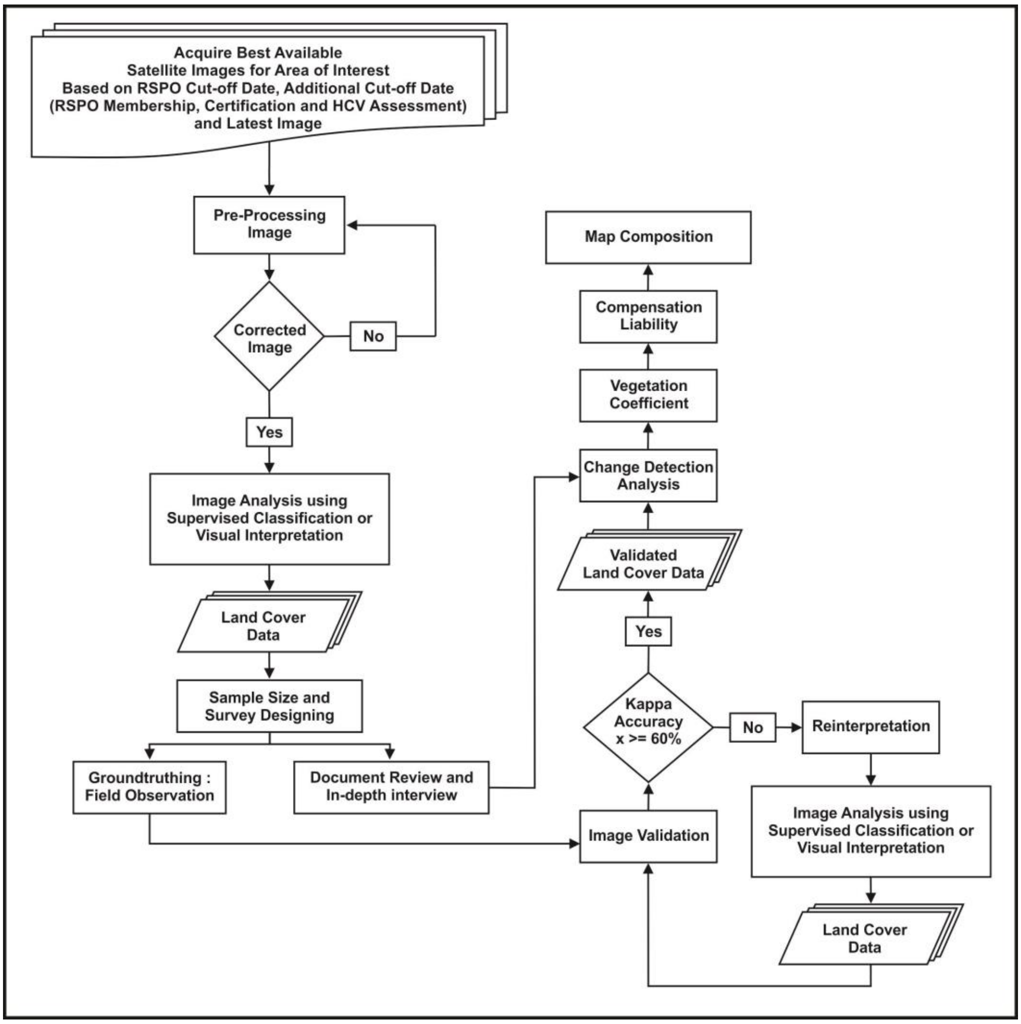

Figure 1. Overall Flowchart for Land Use Change Analysis

The periods that apply in a LUCA differ between companies/management units. The number of periods may become more or less than the number of periods that normally apply as mentioned above. Several periods that should be added to a LUCA are as follow.

(i) The date when the company becomes an RSPO member. This is added as an additional period within one of the periods mentioned above.

(ii) The date when the company receives the results of the HCV assessment (becoming aware of the presence of HCVs within its operational area). Added as the LUCA final cut-off.

The first period should be considered additional due to the consequence the company has to bear because of land clearance without prior HCV assessment. It takes form of a compensation and/or remediation liability following different calculation formulas for between, before and after the cut-off dates (*see* RSPO Remediation and Compensation Procedures, Table 3: Determining Compensation Liability). Whereas, the date when the company receives the HCV assessment result (the first time it is aware of the presence of HCVs in its operational area) is considered as the final cut-off of the LUCA. The next periods after this date is excluded from the LUCA scope (no longer scope of the LUCA).

Therefore, the company must attach data and/or document relevant to the periods in question, namely: (i) the date when the company has become an RSPO member and (ii) the date the company receives the HCV assessment result (the first time it becomes aware of the presence of HCVs within its operational area, be it in the form of an interim report, draft report, or final report).

In the cases where HCV assessments have been conducted prior to land clearance since November 2005 and where known and identified HCVs were subsequently damaged or lost afterwards are not classified as potential Compensation Cases and will instead be treated as a non-compliance with RSPO P&C Criterion 5.2.

2. Selecting Satellite Images

2.a. Satellite Image Resolution

Satellite images appropriate for use in LUCA are those with resolution of at least 30 m. **Table 1** provides information on several usable satellite images and their specifications.

2.b. Satellite Image Quality

A satellite image is considered having good quality if it is clear enough, allowing good land cover interpretation and classification. A good quality satellite image has the following characteristics: (i) free from cloud coverage; (ii) free from haze; and (iii) free from sensory errors.

However, such ideal conditions often cannot be met by a satellite image of a specific acquisition date. For the land cover interpretation, toleration is allowed to the extent that the land cover classification can still be interpreted and generate accountable outputs. If the tolerable limit cannot be met, options should be made for actions to address such situation (*see* **Table 2**).

2.c. Date of Acquisition

The LUCA is carried out using several dates of acquisition of satellite images. Satellite images usable are ideally those representing the said cut-off dates, i.e. 1 Nov 2005, 31 Nov 2007, 1 Dec 2007, 31 Dec 2009, 1 Jan 2010, 9 May 2014, the date the company became RSPO member and the date the company became aware of the presence of HCVs in its operational area.

Where a good quality satellite imagery (appropriate for land cover interpretation and classification) on the said dates is not found due to one or more factors related to the condition described in the previous section (**2.b. Satellite Image Quality**), satellite images from other dates have to be used to replace or be combined with the existing satellite images from the acquisition date. Rules apply to the search for satellite images from the replacing acquisition dates for use in the land cover interpretation and classification (*see* **Table 1**).

Table 1. Examples of satellite image usable for LUCA

Satellite	Pixel Size (m)	Spatial Resolution	How To Get	Note
WorldView	< 1	Very High	Purchase Order	2-3 week order, not recommended for time series analysis, expensive and time consuming
GeoEye			Purchase Order	2-3 week order, not recommended for time series analysis, expensive and time consuming
GeoEye (EO-1)			http://earthexplorer.usgs.gov/	Not all land areas are covered by this satellite
QuickBird			Purchase Order	2-3 week order, not recommended for time series analysis, expensive and time consuming
IKONOS	1-10	High	Purchase Order	2-3 week order, not recommended for time series analysis, expensive and time consuming
ASTER	10-100	Moderate	Purchase Order	1-2 week order, time series availability, recommended
AVNIR			Purchase Order	1-2 week order, time series availability, recommended
ALOS PALSAR1			http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm	Time series availability, free of charge but only covers the period 2006-2011, recommended as supporting images to the main satellite image used.
LANDSAT LEGACY			http://earthexplorer.usgs.gov/	Time series availability, free of charge, recommended
LANDSAT Archive			http://earthexplorer.usgs.gov/	Time series availability, current image are available, free of charge, recommended
SENTINEL-2			http://earthexplorer.usgs.gov/	Time series availability, free of charge but no imagery is available before December 2015, recommended as supporting images to the main satellite image used
SPOT 1 - 7			Purchase Order	1-2 week order, recommended

Satellite images with coarse and very coarse spatial resolutions with large pixel size such as MODIS and MERIS (pixel size of 100-1,000) or AVHRR (pixel size of >1,000) are not recommended for use in LUCA for RSPO Remediation and Compensation.

Box 1. Example for setting LUCA periods and cut-off

<u>Example 1:</u>
A certain company becomes an RSPO member on 12th August 2007 and receives the results of the HCV assessment on 30th June 2008. The LUCA periods and cut-off which apply to this company are as follow.

1. 1 Nov 2005 – 12 Aug 2007
2. 12 Aug 2007 – 31 Nov 2007
3. 1 Dec 2007 – 30 Jun 2008

Therefore, satellite images to be analyzed should be acquired on the following dates.

1. 1 Nov 2005 or the previous date in order to identify the initial condition of the land cover in the assessment area (baseline).
2. 12 Aug 2007 or later image in order to identify scope of lands that have been cleared prior to HCV assessment.
3. 31 Nov 2007 or later image in order to identify scope of lands that have been cleared prior to HCV assessment once the company becomes an RSPO member.
4. 30 Jun 2008 or later image in order to identify scope of lands that have been cleared prior to HCV assessment at the time when HCV assessment result is received by the company (the date for the first time the company is aware of the presence of HCVs in its operational area)

<u>Example 2:</u>
A company becomes an RSPO member as of the date of 28th October 2011 and receives the HCV assessment results on 17th September 2013. Therefore, LUCA period and cut-off that apply to this company are as follow.

1. 1 Nov 2005 – 31 Nov 2007
2. 1 Dec 2007 – 31 Dec 2009
3. 1 Jan 2010 – 28 Oct 2011
4. 29 Oct 2011 – 17 Sep 2013

Therefore, satellite images to be analyzed should be acquired on the following dates.

1. 1 Nov 2005 or the previous image to identify the initial condition of the land cover in the assessment area (baseline).
2. 31 Nov 2007 or a later image to identify scope of lands that have been cleared prior to HCV assessment before the company becomes an RSPO member by the end of the 1st period, which is also the beginning of the 2nd period of remediation and compensation procedure implementation.
3. 31 Dec 2009 or a later image to identify scope of lands that have been cleared prior to HCV assessment by the end of 2nd period, which is also the beginning of the 3rd period of remediation and compensation procedure implementation (after the RSPO NPP have taken effect).
4. 28 Oct 2011 or a later image to identify the scope of lands that have been cleared prior to HCV assessment after the company became an RSPO member.
5. 17 Sept 2013 or a later image to identify the scope of lands that have been cleared prior to HCV assessment at the time the company receives the HCV assessment results (date when the company becomes aware for the first time of the presence of HCVAs within its operational area).

Table 2. Optional actions in case of problems occur with satellite images from the required dates

Problem	Options of action
1. Satellite images from the cut-off dates are covered with clouds of more than 20% of the assessment area (company's legally permitted area during the assessed period).	1.a. Use satellite images from other dates of acquisition whose cloud coverage is below 20%.
	1.b. Search for satellite images from other dates of acquisition. In this case cloud coverage of above 20% is allowed, but cloud must be located at the positions different from those on the first image. Combine them with the first satellite image. The closer the time gap from each other, the better. The most important thing is that use of satellite images from different dates for one single cut-off shows no significant changes of land cover (Zhu *et al*. 2012), for guidance please refer to Table 3.
2. Satellite image from the acquisition date contains significant noise (e.g. striping on Landsat 7).	2.a. Use satellite images from other acquisition dates that are noise-free (e.g. free from striping satellite image such as Landsat 5 TM).
	2.b. Search for satellite images from other acquisition dates. In this case they may contain striping, but the strips must be located at the positions different from the first image. Use these satellite images as the filler to the first satellite image.
3. Satellite image from the acquisition dates contains significant noise in the form of haze.	3.a. Search for satellite images from other dates of acquisition that are haze free. Should they contain cloud coverage of above 20%, proceed with action 1.a or 1.b. Use these satellite images to replace.

Note: *See* **Table 3** for guidance to search for satellite images to replace the image of the required cut-off date

Table 3. Guidance to search for satellite images to replace the image of the required cut-off date

Case	Action	Note
1 Nov 2005 acquisition image is not of good quality	Search for and use images from acquisition prior to 1 Nov 2005	Wherever possible 1-3 months earlier (or 6 months at the longest). The further the acquisition date is from the date in question, the more differences to be potentially happened in the land cover conditions.
31 Nov 2007 or 1 Dec 2007 acquisition image is not of good quality	Search for and use images from acquisition after 1 Dec 2007	Wherever possible, 1-3 months afterwards (or 6 months at the longest). The further the acquisition date is from the date in question, the more differences to be potentially happened in the land cover conditions.
31 Dec 2009 or 1 Jan 2010 acquisition image is not of good quality	Search for and use images from acquisition after 1 Jan 2010	
9 May 2014 acquisition image is not of good quality	Search for and use images from acquisition after 9 May 2014	
Acquisition image on the date when the company became RSPO member is not of good quality	Search for and use images from acquisition after the date in question	
Acquisition image on the date when the company obtained RSPO certificate is not of good quality		
Acquisition image on the date when the company firstly knew of the presence of HCVAs in its operational area is not of good quality		

3. Image Pre-processing

All data from satellite image are biased (due to error or distortion), including both geometric and radiometric distortions.[5] This is because the data recorded by sensor is greatly affected by atmospheric conditions, the angle of data capture from the sensor, and the time when the data is taken. This distortion needs to be corrected before it can be used as the basis for interpretation and classification of land cover, during the image pre-processing stage.

The image pre-processing operation aims to correct distorted or degraded image data to create a more reliable representation of the original scene. Image pre-procession consists of two stages: (i) Radiometric corrections and (ii) Geometric corrections.

3.a. Radiometric Corrections

The radiometric correction is aimed at restoring an image to as close to the original scene as possible. It involves haze correction (using regression adjustment and/or histogram adjustment methods), line dropout errors and line stripping/banding errors corrections. The radiometric correction becomes relevant for comparing remote sensing data with ground truthing data or comparing data acquired at different times by different sensors for change detection (Bakker *et al*., 2009).

3.b. Geometric Corrections

The geometric correction is aimed at rectifying geometric errors introduced in the imagery during the process of its acquisition. It is the process of transformation of a remotely sensed image so that it has the scale and projection properties of a map. Geometric corrections account for various geometrical errors during the scanning of the sensor, movement of platform, and earth curvature.

Geo-coding and geo-referencing are the often-used terms in connection with the geometric correction process. The basic concept behind geo-coding is the transformation of satellite images into a standard map projection so that image features can be accurately located on the earth's surface, and the image can be compared directly with other sources of geographic information (such as maps). The allowed minimum threshold correction (RMS error) for geo-referencing is 0.5 pixels.

The construction of satellite image composite for generating the desired information can commence after the correction of the raw data from the satellite image (through the process of geometric and radiometric corrections) and after each satellite image with different acquisition dates is assigned with a Digital Number (DN) and projections matching one to another, the construction of satellite image composite for generating the desired information can commence (false colour composite: for Landsat 8 OLI use band composition RGB 654, for Landsat 5 TM and Landsat 7 ETM+ use band composition RGB 543).

4. Image Analysis

The satellite image is analysed to extract information contained in this corrected satellite image. The information to be extracted is land cover in each satellite image used for classification into each category or type of land cover.

Land interpretation and classification can be carried out with one of the following methods, or in combination: (i) supervised classification (region of interest-ROI and area of interest-AOI) is carried out by interpreter and classification process is performed with computation); (ii) unsupervised classification (the whole classification process is performed with computation); and (iii) object-based visual interpretation with on-screen digitizing (interpreter sets and digitizes all objects manually).

An important thing to be noted in performing object-based visual interpretation is human vision of the interpretation element. Human vision relates to the interpreter's personal capacity (knowledge, skills and experience) that affects his/her spontaneous recognition and logical inference. As for the interpretation element, it is a visual characteristic of a satellite image that includes colour and its brightness, texture, pattern, shape, size, height, location or association (Bakker *et al.*, 2009). Human vision and interpretation play a significant role in distinguishing corporate from non-corporate land clearings. Therefore, a qualified and experienced satellite image interpreter with local knowledge of the area is required in the LUCA to ensure the interpretation process was conducted properly and accurately.

Each process of land cover interpretation and classification above depends on the quality of the used satellite image. The classification process with the computation method is not recommended for satellite images with high noise content (containing striping, i.e. Landsat ETM+7).

Land cover is classified referring to the Land Cover Classification System of the United Nations Food and Agriculture Organisation (LCCS-UNFAO) and ISO 19144-1 Geographic Information Classification System Part 1: Classification System Structure. For countries that already have national standards for land cover classification, it is carried out referring to these standards (e.g. Indonesia has SNI 7645:2014 on Land Cover Classification and SNI 8033:2014 on Forest Cover Change Calculation Method based on the Result of Optical and Visual Remote Sensing Image Interpretation). The LUCA team is allowed to further classify the land cover under particular standard land cover class (e.g. classifying into high, medium, or low-density vegetation categories, bare soil and water bodies).

Image analysis is performed for each satellite image acquired (the cut-off dates or replacing cut-offs) and to the satellite images from the most recent date (date when the LUCA is carried out). The most recent satellite images are needed as the baseline image for designing survey and validating the land cover interpretation and classification result.

5. Land Cover Data

Land cover data for each cut-off and the most recent dates are generated from the image analysis process. Land cover data takes form of vector spatial data in GIS digital format. It will then be presented in the form of land cover class map completed with legends, scale, orientation, and data and map sources.

6. Survey Designing

Survey designing is an initial stage in performing an accuracy assessment. It includes three fundamental steps: (i) designing the accuracy assessment samples; (ii) collecting data for each sample; and (iii) analysing the results (Eastman, 2001). The reasons for performing an accuracy assessment are to know how good a map has been prepared, to increase the quality of the map information by identifying and correcting the source of errors, and whether or not the information derived from remote sensed data is to be used in some decision-making process (Congalton & Green, 2009).

Determination of the survey locations for ground truthing is carried out using a sampling method. Stratified representative sampling can only be applied if the data to be mapped is qualitative (nominal and ordinal). For mapping of quantitative data (interval or ratio data), unbiased sampling strategies (i.e. random or systematic sampling) should be applied to allow statistical analysis (Bakker *et al*., 2009). Combination between several sampling methods may gather advantages of each method involved for both obtaining qualitative and quantitative data.

Congalton and Green (1999) and Stehman (2009) recommended a minimum of 50 samples for each type of land cover category in the error matrix as a general guideline for planning purposes (for area <250.000 ha and category <12 class). However, other sample number determination methods can also be used. In LUCA as part of RSPO Remediation and Compensation Procedures, number of samples for ground truthing is determined using the Taro Yamane formula (1967):

$$n = \frac{N}{N.e^2 + 1}$$

Where:

n = the number of samples

N = the number of populations

e^2 = the precision that is set (in this case minimum and maximum precisions are set, i.e. on the Confidence Interval (CI) of 95% and 90%, if CI = 95; p=0.5)

Source of reference data can be previously collected data and newly collected data (Congalton & Green, 2009). Reference data is data collected during ground truthing for comparison with the interpreted land cover class in performing an accuracy assessment. The existing data is usually collected for purposes other than an accuracy assessment. Often the measurements made on the plot cannot be transformed into measurements useful for the accuracy assessment. However, the existing data can be used as a reference data to validate the land cover data derived from image analysis of the previous acquisition date (previous cut-off date). In-depth interview is also a part of ground truthing process. This can validate the historical information about how the land cover has changed periodically.

In a certain case, one or more land cover classes found in previous periods are currently no longer in existence in the area of interest ("lost land cover class"). To overcome this situation the LUCA Team has to expand the area of interest until the team find land cover class that has the key interpretation similar to the one of the lost land cover class. The number of sample points must be at least the same with the number of sample points from the lost land cover class.

7. Field Verification

Land cover data resulted from image analysis should represent the actual conditions in the field. Therefore, field verification is ultimately necessary (Bakker *et al*., 2009). This activity may be carried out upon planning of data collection (i.e. survey designing). It includes three parallel activities, i.e. (i) ground truthing; (ii) document review; and (iii) interviews.

7.1. Ground truthing

Ground truthing is conducted to obtain reference data to be used in the accuracy assessment. Reference data collection can be carried out using observation/visual call, field measurement methods (Congalton & Green, 2009), or biomass measurement method (Bakker *et al*., 2009). Observation/visual call is carried out by observing the vegetation consisting of dominant species and crown closure. Field measurement is conducted on a fixed-radius plot to record species, diameter at breast height (DBH) and height of every tree within the plot. Biomass measurement will provide more precise reference data. Measurement data can be used as a quantitative data to justify the land cover data (i.e. primary forest, good quality secondary forest, degraded secondary forest, old-shrub, shrub, bush, barren land or other land cover types).

Biomass measurement will generate useful reference data. However, biomass value alone cannot be subsequently used in determining land cover class without other supporting information for (i.e., land cover description, land-use history, species dominance, vegetation structure, vegetation composition). For example, a primary forest in one certain place might have similar biomass value with secondary forest in other areas. Likewise old shrubs in a particular place with ones in other places. Hence biomass value is better used for rectifying the results of land cover classification instead of determining land cover class. Therefore, in LUCA, the use of biomass measurement method should be accompanied with other methods that can describe field condition, i.e observation/visual call and/or field measurement.

The measured data from ground truthing is categorised as 'newly collected reference data' that can be used for accuracy assessment (*see* **Section 6-Survey Designing**). Ground truthing focuses on searching for land cover baseline similar to the condition of the land cover in November 2005 and the existing land cover types in the assessment area.

7.2. Interviews

Collection of information on land cover baseline is also carried out using in-depth interview with key respondents such as ex-land owners whose lands have been compensated and cleared, enclave owners, those who clear lands, and local communities deemed to have sufficient and/or important information on the former land cover conditions and degrading activities such as logging, clearing and fires.

Verification and validation should be performed to clarify this secondary information, through a triangulation process which can show the accuracy of information that a respondent gives by asking the same question to other, unrelated sources. The verification process is also carried out by making comparison between data and information from respondents and trustworthy information based on secondary references and related company documents.

7.3. Document review

A thorough document review conducted by the LUCA assessors involves documents that provide relevant information to obtain an overview of the land cover before clearing (e.g. land acquisition and compensation documents, documents of land clearing service payment to contractors, land clearing progress documents, land clearing SOP, planting year data), environmental documents (e.g. EIA, Environmental Impact Mitigation Plan, Environmental Impact Monitoring Plan) and HCV reports.

These documents normally contain information on land cover condition, use of land and natural resources and socio-cultural conditions in the past. Data in the land acquisition and compensation documents, as well as other data on land clearing progress and planting year that contain spatial and/or georeferenced information can be classified into the previously collected/existing data (*see* **Section 6-Survey Designing**).

8. Image Validation

The image validation process has actually started since the stage of survey designing (*see* **Section 6-Survey Designing**). This section provides analysis of accuracy assessment that constitutes the end stage of image validation. A vital step in the classification process is the assessment of the accuracy of the land cover data produced from image analysis (Eastman, 2001). The accuracy assessment compares between the classification result and actual condition derived from the field verification (Bakker *et al*., 2009). The output from image validation is the level of accuracy.

> "Validation of two or more consecutive land cover maps with reference datasets is a difficult task, because acquiring reference data for multiple years over large areas can be unfeasible, even if auxiliary maps exist at certain dates. Adequate reference data is particularly elusive if land cover products span a historical period. In such cases, manual interpretation of the Landsat time-series data is becoming an accepted approach for generating the required reference data (Cohen *et al.*, 2010). In some cases, when the examples of past land covers have been lost nowadays (example land cover outside scope study that exist are hardly to find), collecting reference using high-resolution image interpretation data with the same range of dates are recommended. In the change-based updating approach, if the area changed is proportionally small, the accuracy of land cover maps in a time series is often assumed to be close to that of the base map (Pouliot and Latifovic, 2013). In theory, validation of a time series of land cover and change detection results can be achieved with independent error matrices (Mertens and Lambin, 2000; Yuan *et al.*, 2005). However, to ensure robustness, this approach requires no-change samples to be acquired as a component of the reference data (Olofsson *et al.*, 2014). Post-classification comparison of a time series of land cover maps can aid in identifying illogical land cover transitions in space and time (Liu and Cai, 2012), which, in well-registered maps of the same spatial resolution, can be indicative of classification error (Townsend *et al.*, 2009). Moreover, explicit information of change incorporated in land cover products provides a powerful tool for self-assessment and validation. The temporal consistency between consecutive maps can, to some extent, be evaluated against land cover changes. Acceptable land cover transitions in consecutive maps should conform to the time interval separating them, that is, short intervals impose tighter restrictions and provide more reliable judgement. For example, in an annual series of land cover maps, grassland can transit to pasture but not to open forest, but the same transitions would be more uncertain in a five year period. Permitted transitions between land cover classes provide a means for self-assessment, but only partially, because even ecologically logical class transitions could be incorrect." (Gomez *et al.*, 2016).

There are few different methods for image validation and the LUCA assessor can select the appropriate one. The Kappa Accuracy is the common method used in this process (*see* **Box 2** for the application of this method as an example method for image validation).

9. Change Detection Analysis

Upon the complete validation of all land cover data by cut-off dates, and achievement of the desired level of accuracy, the next stage is the change detection analysis, which is a process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). The change detection analysis aims to detect changes in land cover over different

Box 2. Example of image validation process: Kappa Accuracy

The contingency matrix (or confusion matrix, error matrix) is normally used to identify the level of accuracy. Appropriate per-pixel accuracy rationed against the number of misclassified pixels is called *overall accuracy* (Lillesand & Kiefer, 1994). However, the use of this accuracy alone is not sufficient to prove the validity of the interpretation and classification result that has been carried out as this accuracy calculation has tendency of overestimating, so that this classification accuracy analysis also involves calculation of Cohen's Kappa Accuracy (1960).[a] **Table Box 2** below indicates the form of contingency matrix.

Table Box 2. Contingency matrix used to test land cover classification accuracy

	Reference Class			∑pixel	User Accuracy
	A	B	C		
Classified Class					
A	X_{AA}	X_{AB}	X_{AC}	X_{A+}	X_{AA} / X_{A+}
B	X_{BA}	X_{BB}	X_{BC}	X_{B+}	X_{BB} / X_{B+}
C	X_{CA}	X_{CB}	X_{CC}	X_{C+}	X_{CC} / X_{C+}
∑pixel	X_{+A}	X_{+B}	X_{+C}	N	
Producer Accuracy	X_{AA} / X_{+A}	X_{BB} / X_{+B}	X_{CC} / X_{+C}		

Source: Lillesand & Kiefer (1994).

Mathematically, the accuracy test is formulated as follows (Cohen, 1960):

$$OA = \frac{\sum_i^r X_{ii}}{N} \times 100 \qquad K = \frac{N\sum_{i=1}^r X_{ii} - \sum_{i=1}^r X_{i+}X_{+i}}{N^2 - \sum_i^r X_{i+}X_{+i}}$$

Where:
OA = Overall Accuracy
K = Kappa Accuracy

Interpretation of the calculated Kappa accuracy value is described as follows:

	Poor	*Slight*	*Fair*	*Moderate*	*Substantive*	*Almost perfect*
Kappa	0.0	0.20	0.40	0.60	0.80	1.0

Kappa	**Kappa Value Interpretation**
< 0	Poor opportunity of accuracy
0.01 – 0.02	Slight opportunity of accuracy
0.21 – 0.40	Fair opportunity of accuracy
0.41 – 0.60	Moderate opportunity of accuracy
0.61 – 0.80	Substantive opportunity of accuracy
0.81 – 0.99	Almost perfect opportunity of accuracy

Source: Cohen (1968).

Basically, a Kappa accuracy value of 50%-90% is acceptable. However, taking into consideration that the LUCA result will be used to precisely calculate the company's compensation liability, Kappa coefficients above 0.60 are used as a threshold as acceptable accuracy values. In the field of remote sensing, a Kappa coefficient greater than 0.6 indicates that the interpretation result is sufficiently accurate, hence acceptable. Therefore, no reinterpretation is required.

If the value of Kappa coefficient generated falls below 60%, reinterpretation of the land cover data resulted from the image analysis will be necessary. This is important to enhance the quality of land cover data resulted from image analysis and correct sources of errors which cause a low Kappa coefficient. This process is conducted repeatedly until the Kappa coefficient reaches >60%.

At this stage, satellite image is also validated using previously collected/existing reference data (*see* **Section 6-Survey Designing** and **Section 7-Field Verification**). Data on land cover, both in the past and present, is corrected using the land clearing history data, coverage data and land acquisition that contain spatial information. As already mentioned in the previous part, validation that employs previously collected/existing reference data cannot be used for accuracy assessment analysis.

time intervals. There is an important aspect of change detection when monitoring natural resources: (i) detecting changes that have occurred; (ii) identifying the nature of the change; (iii) measuring size of the changing area; and (iv) assessing the change's spatial pattern (Macleod & Congalton 1998). Many techniques have been developed which can be organized into (i) algebraic/statistical; (ii) change vector/transformation; (iii) classification; or (iv) a combination of the former techniques (Pathak, 2014).

10. Identifying and distinguishing non-corporate land clearances from corporate land clearance

The grower members cannot be held responsible for all clearance of land since November 2005 prior to coming under their management. In particular, the RSPO encourages members to expand onto appropriate land, which may have been cleared by individuals or other groups for their own use. Therefore, in several cases, the Remediation and Compensation Procedure distinguishes between corporate and non-corporate land clearances (see Glossary for definitions), whereby growers are not required to compensate for land, which they can demonstrate, was due to non-corporate land clearance.

Non-corporate land clearance is defined as land clearance for other than corporate purposes. It includes land clearances conducted by the local community to support their livelihood and government projects that involve public works or other public interest facilities and infrastructures (e.g. road, canal, port). There are cases where, within the company/management unit concession, development and/or exploitation activities were conducted by other parties which also hold official concession or license issued by the government, therefore, not under control of the company/ management unit (e.g. mining concession, oil and gas concession). These types of land cover degradation or clearances are also categorized as non-corporate land clearances. Includes in non-corporate land clearance is land cover change or degradation caused by natural disturbances (e.g. fire, landslide).

Identifying non-corporate land clearance (distinguishing it from corporate clearance) is carried out throughout the LUCA process, starting at the satellite image interpretation to the field verification and up until the change detection analysis. The combination of several indicators can be used in this process of verification: the size, rate, pattern and shape of the cleared lands. In order to ensure the land clearance is in actual fact categorized as non-corporate land clearance instead of corporate land clearance, supporting documents and additional information are required.

Corporate land clearance. On the satellite image, the corporate land clearance is recognizable. It is apparent, so it can even be detected and distinguished during the LUCA pre-assessment stage of satellite image interpretation. It has characteristics which make it distinct from cleared land by local community as well as land cover change or degradation caused by natural disturbances. The size of cleared land is relatively large, the clearance process is relatively rapid (100-300 ha/month), the pattern of the cleared land is systematic (one or few large blocks which are interconnected, not sporadic), and the shape of the cleared land is usually square with straight borders. Additional feature which can indicate the land cover change or degradation caused by corporate clearance is the occurrence of roads which connect one block or more of cleared lands with the others and/or with the existing road networks.

Land clearance conducted by local community. This type of land clearance has contrasting characteristics from the corporate land clearance. It is characterized by the size of cleared land which is relatively small (the size may differ from one country to another; it is ranging from 3 to 6 ha in Indonesia), the distribution pattern is scattered throughout the assessment area and often also outside the legal boundary of the company/management unit, with very limited or no connecting roads.

Land clearance caused by the government projects and/or activities of other parties. To verify the existence and coverage of those activities, the combination of field verification, document review and interview with the management unit staff, local government, local community and other key respondents are required.

Land cover change or degradation caused by natural disturbances. Land cover change or degradation occurs not only because of the impact of human activities but can also be caused by natural disturbances, such as fire or landslide. It is possible to identify and distinguish it from the corporate land clearance. The size of cleared land cannot be used as an indicator for this type of "land clearance" as the impact of natural disturbances can be massive in some cases or places but limited in other cases or places. However, the pattern and shape of the cleared land, which is not systematic and not square with straight border, can indicate whether the land was cleared by the company/management unit or degraded by natural disturbances.

Identifying non-corporate land clearance, including land cover change or degradation caused by natural disturbances, and distinguishing them from corporate land clearance should be conducted properly by involving a careful and thorough verification process and supported by strong evidences. At the stage of satellite image interpretation, the assessment team should look through the size of cleared land, as well as its pattern and its shape, and the occurrence of road.

During the ground-truthing, the assessment should spend sufficient time for reviewing all documents related to land clearance (e.g. land clearance data and map, planting year map, land compensation data and map) and conducting in-depth interview with local community members and other key respondents who have knowledge on historical events related to land cover change in the assessment area (e.g. natural resource exploitation and land utilization carried out the community as well as other parties, land preparation practiced by the community including use of fire for slash-and-burn practices, development and/or exploitation activities of other parties, natural catastrophe that happened to the area in the past).

Verification and validation should be performed to strengthen the information received from the respondents, through a triangulation process which can show the accuracy of information that a respondent gives by asking the same question to other unrelated sources. The verification and validation process is also carried out by making comparison between data and information from respondents and trustworthy information based on secondary references and company documents.

The claim for land cover change or degradation caused by natural catastrophe has to be supported with strong evidences, such as satellite image showing the hotspots of land and/or forest fires (e.g. NOAA) and documentation photos showing the landslide. Where strong evidences are not provided and the satellite image is not distinctive, the cleared land will be categorized as corporate land clearance. Data separation for corporate clearance and other clearances (of community, government, other parties, or natural disturbance) provided by the company (in the *.shp file format) will be an advantage for the verification process. It will accelerate the process of ensuring the types of clearances.

11. Categories of land cleared without prior HCV assessment: vegetation coefficients

The land cover data for each cut-off date, that has been confirmed valid, is then classified into four categories representing the forest/habitat types and other land uses that may be identified using satellite image. This grouping aims to simplify the land cover data into four classes of vegetation coefficient (*see* **Table 4**). They represent a sliding scale of habitat quality, ecological and conservation value, which are assigned coefficients between 1.0 and 0.0 and are used as multipliers in the calculation of conservation liability.

The classification of vegetation into the coefficient categories will be based on satellite image analysis and supplementary documentary evidence. During the ground truthing, the land cover class of multi-species agroforestry is relatively easy to distinguish from other land cover class. The occurrence of agricultural plant species mixed with forest tree species and other natural vegetation is an obvious indicator for this land cover class. However, to extrapolate the extent of this land cover class in the assessment area in order to calculate the loss of this land cover class is not possible, since, on the satellite image, this land cover class looks very similar - therefore it cannot be distinguished- from other land cover class (e.g. secondary forest, old-shrub, shrub, bush; depend on the stage of succession was taking place in the agroforestry area).

To ensure the land cover class in question is multi-species agroforestry (vegetation coefficient 0.4) instead of a good quality secondary forest (vegetation coefficient 1.0) or degraded secondary forest (vegetation coefficient 0.7), the reporting company/management unit has to provide additional information and evidences, such as geo-referenced photos of the areas in question, land compensation documents with exact location and/or its geo-reference describing the land cover type and compensated plants, land clearance documents with exact location and/or its geo-reference describing land cover information which was cleared. Where such evidence is not provided and the satellite image is not distinctive, the higher coefficient category should be used.

Table 4. Vegetation Coefficients

Vegetation Coefficient	Description
1.0	**Structurally complex forest with uneven or multi-layered canopy** This category includes forest that has been subjected to low intensity selective logging and/or is at a late stage of recovery after long rotation shifting agriculture. Coefficient 1.0 also includes closed-canopy swamp, mangrove, and peatland forests with no signs of drainage.
0.7	**Structurally simplified or degraded forest with even or single-layered canopy** This category includes forest regenerating after large-scale disturbance including intensive and/or recent logging, wind and/or fire damage (or some combination of these factors). Coefficient 0.7 also includes swamp, mangrove, and peatland forests regenerating after logging or other disturbance.
0.4	**Multi-species agroforestry** This category includes agroforestry farms and plantations which comprise multi-species 'mosaic' largely dominated by mature tree crops and retaining some structural complexity.
0.0	**Highly modified and/or degraded areas retaining little or no natural, structurally intact vegetation** This category includes monoculture plantations, permanent fields, pasture, open developed and/ or degraded grass or shrub lands.

Notes: Interpretation of these coefficients should make reference to the National HCV identification guidance applicable, or global guidance, at the time of land clearance. In some countries, non-forest ecosystems, e.g. natural savannahs, *cerrados*, grasslands, wetland ecosystems, peat swamps, freshwater swamps, caves and lakes, are identified as HCVs. These should be categorized as 0.4-1.0 according to the national and/or regional context. For such exceptions, the decision on the vegetation coefficient (0.4, 0.7 or 1.0) should be made based on expert judgement, taking into consideration the importance of the area in the international, regional or national context.

12. Map Composition

In principle, map composition aims to ensure that land cover classification data from image analysis is readable and usable to users in general in the form of land cover thematic maps. All basic information in cartographic products must be presented, making the maps self-explanatory. Every map should at least have a title, legend, scale bar, sources and coordinates.

Map composition can also be arranged based on cartographic standards that apply in every country. Generally standards may vary, although the objective remains the same, which is how to make the map as informative as possible.

13. Reporting

Reporting is a stage of presenting all data that have been collected from the beginning of data collection and the analysis, the compensation liability calculation and the final compensation liability for the reporting company/management unit. The development of LUCA report must be following the **LUCA Reporting Template** and completed with all required associated attachments and files as specified in the **LUCA Reporting Annex.**

Reference

Bakker, W., Feringa, W., Gieske, A., Gorte, B., Grabmaier, K., Hecker, C., Horn, J., Huurneman, G., Janssen, L., Kerle, N., Meer, F., Parodi, G., Pohl, C., Reeves, C., Ruitenbeek, F., Schetselaar, E., Tempfli, K., Weir, M., Westinga, E., and T. Woldai. 2009. *Principle of Remote Sensing: An introduction textbook.* The International Institute for Geo-Information Science and Earth Observation (ITC). The Netherlands.

Cohen, J. 1960. A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*. Vol. 20 (1): pp. 37-46.

Cohen, J. 1968. Weighted Kappa: Nominal Scale Agreement with Provision for Scaled Disagreement or Partial Credit. *Psychological Bulletin* Vol. 70: pp. 213-20.

Congalton, R.G., and K. Green. 2009. *Assessing the accuracy of remotely sensed data – Principles and practices. 2nd ed*. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Eastman, J.R. 2001. *Guide to GIS and Image Processing. Volume 1*. Clark University, USA.

Lillesand, T.M. and R.W. Kiefer. 1994. *Remote Sensing and Image Interpretation, 3rd ed.* John Wiley & Sons. New York, Chichester, Brisbane, Toronto, Singapore.

Macleod, R.D., and R.G. Congalton. 1998. A quantitative comparison of change detection, algorithm for monitoring Elegrass from remote sensing data. *Photogrammetric Engineering and Remote Sensing.* Vol. 64(3), pp. 207-216.

Pathak, S. 2014. Change detection techniques to monitor land cover dynamics in mine environment. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Volume XL-8.

RSPO. 2014. *RSPO Remediation and Compensation Procedures Related to Land Clearance without Prior HCV Assessment.* RSPO.

RSPO. 2015. *RSPO Remediation and Compensation Procedures Related to Land Clearance without Prior HCV Assessment:* Approved by Consensus of Compensation Task Force on November 12th, 2015. RSPO.

Singh, A. 1989. Digital change detection techniques using remotely sensed data. *International Journal of Remote Sensing*. Vol. 10(6), pp. 989-1003.

Stehman, S.V. 2009. Sampling designs for accuracy assessment of land cover. *International Journal of Remote Sensing*. 30, 5243-5272.

Yamane, T. 1967. *Elementary Sampling Theory*. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Zhu, X., Liu, D., and J. Chen. 2012. A new geostatical approach for filling gaps in Landsat ETM+ SLC-off images. *Remote Sensing of Environment.*

Explanatory Notes

1 **Legal boundary as LUCA area scope**. In order to start developing a plantation, the company is usually received a work area permit with legally determined boundaries. The company is only allowed to develop its plantation within this legal boundary.

2 **Land cover on 1 November 2005 as a baseline.** The vegetation cover in the scope area on or before 1 November 2005 is a baseline for the LUCA as it shows the initial condition of the land cover in the assessment area before the remediation and compensation procedures come into effect. Any clearings before this date will not lead to any liabilities.

3 **1th January 2010**. The date when the RSPO New Planting Procedures took effect, i.e. where companies became obliged to carry out HCV assessment prior to land clearing and planting.

4 **9th May 2014**. The date when the RSPO Remediation and Compensation Procedures took effect and serious sanctions were put into place for any company/management unit that clears lands or plants oil palms without prior HCV assessment upon this date. This sanction includes the possibility of getting expelled from RSPO membership.

5 **Radiometric errors** are present in the form of noise which is any unwanted disturbance in image data due to limitations in sensing, signal digitization, and data recording process. Radiance measured by a remote sensing system depends upon the following factors: (a) changes in scene illumination; (b) atmospheric conditions; (c) viewing geometry; and (d) instrument response characteristics. The potential sources of these errors are: (i) periodic drift or malfunctioning of a detector; (ii) electronic interference between sensor components, and (iii) intermittent 'hiccups' in data transmission and recording.

Geometric distortions in satellite images can be classified on the basis of the nature and source of errors as follows:

(a) Systematic distortions (stationary in nature). The effect is constant and can be predicted in advance; hence these can be easily corrected by applying formulas derived by modelling sources of distortions mathematically. Various types of errors in this category are: (i) scan skew, (ii) scanner distortion/panoramic distortion, (iii) variations in scanner mirror velocity, (iv) perspective projection, (v) map projection.

(b) Non-systematic distortions (non-stationary in nature). Their effects are not constant because they result from variations in spacecraft altitude, velocity, and attitude and are hence unpredictable. These can be corrected by satellite tracking data or well-distributed ground control points (GCPs) occurring in the image. These distortions occur in two types, based on the correction method: (i) distortions evaluated from the satellite tracking data: earth rotation and spacecraft velocity (ii) distortions evaluated from ground control: altitude variations and attitude variations (pitch, roll, and yaw variations).