EASTERN PROVINCE-JURISDICTIONAL SUSTAINABLE LANDSCAPE PROJECT

STANDARD OPERATING PROCEDURES FOR MAPPING USING REMOTE SENSING

AUGUST , 2023

BioCarbon Fund
Initiative for Sustainable Forest Landscapes

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About the Standard Operating Procedure (SOP)

Standard Operating Procedure			
Version	V1	**Date of Issue**	June 2023
Purpose	This SOP details how to set up and execute data collection for land use mapping approaches to assist in quantifying the amount of carbon within the various organic pools found within a eastern province landscape		
Responsibilities	MRV coordinator a) In coordination with the PIU, the role will entail working with Land Use Planning sector lead officers to deliver high-quality MRV outputs. b) Will serve as a focal point for enquiries regarding national MRV systems. c) Will work closely with forest, energy and agriculture sectors, and private sector partners in developing and maintaining the MRV systems. d) Oversee data collection according to indicators and matrices provided for in the standard operating procedures for Forestry. e) Provide guidance in the development of the sampling framework for Energy, Forestry, and Agriculture. f) Supervise data collection at district and chiefdom level for Forestry.		
Prerequisites	Sampling design are provided in the MRV management plan.		
Related documents	The following are the related documents to be used alongside the SOP: a) MRV management plan b) SOP for biophysical measurements c) SOP for energy d) SOP for agriculture e) ZIFLP-MRV mobile application software f) Integrated Land Use Assessment Phase II Zambia Biophysical Field Manual g) Forest Biophysical Field Data Entry Booklet Integrated Land Use Assessment Phase II Zambia		

ACRONYMNS

EP-JSLP	Eastern Province Jurisdictional Sustainable Landscape Programme
GHG	Greenhouse Gases
GIS	Geographical Information System
GPS	Global Positioning System
ID	Identification
ILUA II	Integrated Land use Assessment Phase Two
IPCC	Intergovernmental Panel on Climate Change
MRV	Monitoring Reporting and Verification
PIU	Project Implementation Unit
PVC	Polyvinyl Chloride
SOP	Standard Operating Procedure
UTM	Universal Transverse Mercator
ZEMA	Zambia Environmental Management Agency
ZIFLP	Zambia Integrated Forest Programme

Common File Formats

DOC Microsoft Word document
DOCX Microsoft Word 2007 (and later) document
EPS Encapsulated Postscript
GDB Geodatabase
GPX GPS exchange
HTML Hypertext Markup Language
JPEG Joint Photographic Experts Group
KML Keyhole Markup Language
KMZ Compressed Keyhole Markup Language File
LYR Esri layer file
MXD Multiple XML documents
PDF Portable Document Format
SHP Esri Shapefile
TXT Text only

1.0 INTRODUCTION-BIOPHYSICAL ASSESSMENTS

The Zambia Integrated Forest Landscape Project (ZIFLP) in Eastern province is supported by World Bank and its objective is to improve landscape management and increase environmental and economic benefits for targeted rural communities in the Eastern Province and to improve Zambia's capacity to respond promptly and effectively to an Eligible Crisis or Emergency.

The project provides support to rural communities in Eastern Province to allow them to better manage the resources of their landscapes so as to reduce deforestation and unsustainable agricultural expansion; enhance benefits they receive from forestry, agriculture and wildlife; and reduce their vulnerability to climate change. Simultaneously, the project is supporting the creation of the enabling environment for subsequent carbon emission reduction purchases. The ZIFLP's key beneficiaries are the rural poor communities of the Eastern province.

The Zambia Environmental Management Agency (ZEMA) with support from ZIFLP have been mandated to develop national and subnational (EP-JSLP) Measurement, Reporting and Verification System (MRV) and other GHG emission-related processes and systems under subcomponent 1.2: Emissions Reduction Framework. With this support, ZEMA will have one integrated and robust MRV that will be used to monitor emissions for the EP-JSLP and at national level.

This document aims to provide for Ecosystem Mapping of forest, grassland, wetlands, and agriculture land cover types and corresponding ecosystems. This document covers the standardized methodology of ecosystem mapping, a general overview of data collection for the training and verification samples, and step-by-step processes and methods for mapping forest, grassland, wetlands, and agriculture types and ecosystems. Remote sensing is a key tool for the monitoring, analysis and restoration of burned areas on a global and regional scale because it provides reliable and quick results and allows rapid diagnosis over burned areas for post-fire mitigation activities. This SOP will also be used to assess burnt areas of forest using remote sensing. This SOP will be used in collaboration with the following:

a) MRV management plan
b) SOP for biophysical measurements
c) SOP for energy
d) SOP for agriculture
e) ZIFLP-MRV mobile application software
f) Integrated Land Use Assessment Phase II Zambia Biophysical Field Manual
g) Forest Biophysical Field Data Entry Booklet Integrated Land Use Assessment Phase II Zambia.

2.0 SOP FIELD SAFETY

Safety is the foremost priority and precautions must be taken and strictly adhered to. Planned field activities must remain flexible and allow for adjustments in response to on-the-ground assessments of hazards and safety conditions. F ield personnel must be well prepared, vigilant and always avoid unnecessary risks. It is recommended that personnel engaging in field activities hold general first aid training[1]. The following guidelines will apply to all field-based activities:

a) Field crews will include no less than two people who must be directly accompanying each other for the entire duration of field work. Ideally field crews should include a minimum of three people; in case of an accident resulting in injury one person may leave to seek help while another person stays with the injured crew member.
b) For each day in the field, specific location and scheduling information must be logged in advance with a point person who can be reached at any time during the anticipated duration of field work. While in the field, crews should check in with their designated point person once per day.
c) Each independent crew must carry a Handheld GPS, radio, satellite phone or cell phone provided by the project. Crews should make sure to check batteries each time before entering the field.
d) Trip planning will include identification of the nearest medical facility and specific directions to reach that facility. When in areas with poisonous snakes, advance communication should be made to verify that appropriate antivenoms are available.
e) Personnel will carry personal identification and, if possible, project name tags at all times.
f) Field crews will carry a first aid kit with them at all times. First aid kits should contain Epinephrin/Adrenalin or an antihistamine for allergic reactions (e.g. bee/wasp stings). Insect repellent should be carried in the field.
g) Where poisonous snakes are common, snake chaps are recommended. In the event of snake bite, the victim should be taken immediately to a medical facility.
h) Basic field clothing should be appropriate for the range of field conditions likely to be encountered. This will include: sturdy boots with good ankle support or rubber boots, long sleeves and pants, rain gear, and gloves. Blaze orange (vest or hat) is recommended when and where hunting may be taking place. Where necessary, to avoid extended contact with plant oils, ticks, and a change of clothes should be made at the end of each day in the field and field clothes should not be re-worn without first laundering.
i) Ensure personnel stay sufficiently hydrated and carry enough clean water for the intended activity. Carry iodine tablets or other water purification tablets in case there is a need to use water from an unpurified source.
j) Some plots may be too hazardous to sample. Situations include: plot center on a

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[1] Sarah M. W et.al, 2012: Standard Operating Procedures for Terrestrial Carbon Measurement

slope too steep to safely collect data (i.e., >100% slope or on a cliff); presence of bees; illegal activities; etc. When hazardous situations arise, a discussion should be conducted among the team members to assess the situation.

3.0 SOP DATA COLLECTION

This SOP will consider measurement and data collection for the generation of land use maps and respective areas of forest, grassland, cropland, settlements, wetland and other land.

Table 3.1 Standard operating procedure for agriculture

Steps	Description
Step 1: Planning the data collection	**Step 1a** Identify data to be collected, tools be used and the data format. Number of sampling plots covering Eastern Province (excluding Chama District) will be determined based on 95% confidence and 5% margin of error. **Step 1 b.** The MRV Coordinator estimates the necessary level of effort for the data collection using the formula; **Step 1c.** The MRV Coordinator identifies the persons who may be involved in the data collection in line with the records in the MRV Management Plan. **Step 1d.** The data collection timeline to be followed is as stipulated in the MRV management plan. **Step 1 e.** The PIU will arrange logistics, including equipment to be used for this exercise
Step 3: Training and calibration	**Step 3a.** As a first step in the data collection, the MRV Coordinator and the Trainer organize and prepare a training event for the persons identified in sub-step 1c as data collectors. All the crew members taking part in mapping should understand the basic ideas behind Geographical Information System, remote sensing and interpretation of satellite imagery and how to use all the materials and equipment to obtain appropriate results needed. The training should cover the following topics as a minimum: **Step 3b.** The Trainer implements the training event following these basic principles: a) Environment for active participation, where participants can share questions and opinions b) Encourage communication between the data collectors c) Record attendance of the collectors d) Assess the capacity of the data collectors at the end of the training and record the results. **Step 3c.** The MRV Coordinator and the Trainer prepare a report summarizing the training actions taken, the attendance and the results of the assessment of capacity.

Steps	Description
Step 4: Distribute the sample units among Data Collectors	**Sub-Step 4a.** The MRV Coordinator in collaboration with MRV Forestry Sector Lead and MRV provincial sector leader decides on sample units to be assessed. **Sub-Step 4b.** The MRV Coordinator allocates sample units to data collectors in each district. The MRV Coordinator uses a list of locations in each district to distribute the samples to the collectors. **Sub-Step 4c.** The Coordinator records the number of sample areas, the Data Collectors assigned to assess those areas.

Step 5: Data collection by Data Collectors	**Step 5.1. Developing forest, grassland, cropland, settlements, wetland and other typology** The developing forest, grassland, cropland, settlements, wetland and other-land typology is developed based on a review of past assessments, analysis and interpretation of secondary data, specifically plot-level data, and consultation with experts. This typology will help ensure the collection of sufficient signatures for each potential type of land use classes and their mapping. The typology, however, may need to be revised (i.e. some types may need merging while some new types may emerge) based on field data. **Step 5.2**. **Selection of satellite images** Select satellite images with a reasonable (1 Kilometer) spatial resolution and which are widely used for ecosystems and forest type mapping by many countries such as sentinel and Landsat. Thus, these imageries ensure compatibility and consistency with national, regional and global forest area mapping and change analysis. **Step 5.3. Pre-processing of images and developing co-variates** Image pre-processing will be carried out using the already established algorithm. It includes geometric correction, topographic correction, radiometric correction, and cloud masking process. Co-variates will be developed from the available bands of such systems such as Landsat and Sentinel2 using band combination, band ratio, band indices (e.g. NDVI, EVI, ENVI), terrain indices (e.g. elevation, slope, aspect), and statistical matrices (e.g. standard deviation, percentile). Those co-variates will be developed from either individual image (Landsat or Sentinel2 etc.) or their combination. These processes will be performed separately in Eastern Province. **Step 5.4. Creation of reference data set** A set of reference data points sufficiently representing all land use classes typologies will be prepared for image classification and validation. The data will be collected from the secondary and primary (field survey) sources. The following activities will be carried out for this purpose. **4.1 Analysis and interpretation of the secondary data** The latest data from the permanent sample plots have been/will be analyzed and interpreted to assign a land use class types to each sample point. With the help of land use class typology , each of the plots need to be defined as an **forest, grassland, cropland, settlements, wetland and other land** type considering the species composition or dominance, particularly species-specific basal area. The data from additional sample plots being assessed by biophysical measurement will also be analyzed and included in the data set. **4.2 Field survey (collection and analysis of primary data)**

	Additional field data are necessary for using them as training data for image classification as well as to check mapping accuracy. Thus, field survey will go hand in hand with the above image classification-related steps. **Step 5.5.** **I**mage classification (generating forest, grassland, cropland, settlements, wetland and other land type map - **I**) The annual and seasonal composites will be classified applying the machine-learning algorithm using training data set and co-variates. Various algorithms, such as Classification and Regression Tree (CART), Random Forest (RF), Support Vector Machine (SVM), and primitive-based approaches will be used for classification. For the forest, grassland, cropland, settlements, wetland and other land types that are confined to a small geographic location and are represented by a small number of samples will be digitized as far as possible. This step will produce the first draft of the forest, grassland, cropland, settlements, wetland and other land type map. **Step 5.6. Accuracy assessment and revision of the draft map (generating forest, grassland, cropland, settlements, wetland and other land map - II)** Accuracy assessment of the draft map will be carried out using the validation data sets. Area- based estimation will be generated to calculate the uncertainty of the map. The same process will be repeated for all maps prepared by using different algorithms. The algorithm which gives the highest accuracy such as No Confusion Matrix will be selected for the final map preparation. The map is considered an acceptable quality with the mapping accuracy above 80% threshold. Where the map accuracy is below 80%, the error areas will be revisited, and corrected and additional data will be used to prepare the final forest, grassland, cropland, settlements, wetland and other land map until the map achieves the accuracy above 80%. Training data will also be re-interpreted (e.g. two or more similar forest, grassland, cropland, settlements, wetland and other land types will be merged) and applied to reclassify the map again. This step will generate the second draft of the forest, grassland, cropland, settlements, wetland and other land map with accuracy above the threshold of 80%. **Step 5.7.** Preparation of explanatory notes An explanatory note for each forest, grassland, cropland, settlements, wetland and other land type (classified in the land use class map - **II**) will be prepared based on the map attributes and the relevant field data. The note will assign an appropriate name to each land use class type and describe it in terms of physical and floristic characters, distribution, area coverage etc. **Step 5.8.** Expert review and generating final land use class map Engage an independent expert panel, comprising foresters, botanists, ecologists and taxonomists to examine the classification of forest, grassland, cropland, settlements, wetland and other land types (land use class type map - **II** produced in Step 6) and the corresponding explanatory notes (prepared in Step 7) and provide feedback to improve the map for a wider acceptance. The mapping team will address the relevant feedback; and the final land use class type map will be produced. **Step 5.9.** Analysis of environmental parameters and preparation of a consolidated physical- environmental map(soil map) **Step 5.10**. Consolidating the number of the forest, grassland, cropland, settlements, wetland and other land types

The high number of the forest, grassland, cropland, settlements, wetland and other land types will result in an exceptionally high number of ecosystem types, which may not be appropriate for management purposes. One of the strategies to reduce the number of ecosystem types to the manageable numbers is to consolidate two or more land use class types (from the final land use class type map produced in Step 8) based on their similarities in vegetation structural formation and key ecosystem services (e.g. habitat of same wildlives) they provide. The assessment of similarities between two or more forest types will be guided by the field data and secondary information.

This step will produce a revised the forest, grassland, cropland, settlements, wetland and other land type map for using it in ecosystem mapping.

Step 5.11. Generating the forest, grassland, cropland, settlements, wetland and other land ecological facets

The physical-environmental maps (Step 9) and the revised the forest, grassland, cropland, settlements, wetland and other land type map (Step 10) will be combined to produce the ecological facets map for covers. Each ecological facet represents an ecosystem type with a unique combination of environmental variables and associated land use class type or vegetation structure.

Step 5.12. Generating the forest, grassland, cropland, settlements, wetland and other land ecosystem map (draft)

The number of ecological facets produced in Step 11 will be practically too high for any effective management and decision-making. Consequently, the ecological facets will be aggregated by merging the less significant classes of some of the parameters, which generates and the forest, grassland, cropland, settlements, wetland and other land Ecosystem map of Eastern Province. Data and land use areas should be provided in the following table.

Land use category	**Year**
IPCC Land Use Category	Area (Ha)
Settlement	
Cropland	
Grassland	
Forest	
Otherland	
Wetland	
TOTAL	

YEAR OF ASSESSMENT	**2008**
Indigenous forest	Area (Ha)
Dry evergreen forest	
Dry deciduous forests	
Moist evergreen forest	
Woodlands (semi-evergreen forests)	
Sub total	

Forest Plantations	Area (Ha)
Eucalyptus	
Pinus	
Sub total	
Total Forest land remaining Forestland	
Managed lands	**Area (Ha)**
Settlements	
Cropland	
Other land (bare land)	
Sub total	
Other natural land	**Area (Ha)**
Wetlands	
Other wooded land (grasslands)	
Sub total	
TOTAL	

Step 5.13 Assess Land use Changes

Assess land use change and prepare information in table below

2008 to 2018 Forest land converted to settlement	Area of forestland in Previous year (Ha)	Forestland converted to SL (Ha)	Forestland less SL in Current year (Ha)
Dry evergreen forest			
Dry deciduous forests			
Moist evergreen forest			
Woodlands (semi-evergreen forests)			
Sub total			
Forest land converted to cropland	**Cropland in previous year 2018 (Ha)**	**Forestland converted to CL (Ha)**	**Cropland in current year (Ha)**
Dry evergreen forest			
Dry deciduous forests			
Moist evergreen forest			
Woodlands (semi-evergreen forests)			
Sub total			
Forest land converted to grasslands	**Grassland in previous year (Ha)**	**Forestland converted to GL (Ha)**	**Grassland in currently year (Ha)**
Dry evergreen forest			

Dry deciduous forests			
Moist evergreen forest			
Woodlands (semi-evergreen forests)			
Sub total			
	Forestland in previous year (Ha)	Cropland converted to Forestland FL (Ha)	Forestland in current year Total (Ha)
	Cropland in previous year	Grassland converted to Cropland	Cropland in current year (Ha)
	Grassland in previous year	Cropland converted to Grassland (Ha)	Grassland in current year (Ha)
	Grassland in previous year	Wetland converted to Grassland (Ha)	Grassland in current year (Ha)
	Settlement in previous year	Cropland converted to Settlement (Ha)	Settlement in current year (Ha)

Step 5.14: Area Burnt in Forest Fires

Using satellite data from Sentinel conduct the following:

1. Produce fire severity maps and calculate time series areas affected by fires. Data Collection: Gather data sources such as satellite imagery, weather data, terrain data, and historical fire data. Use remote sensing techniques to detect active fires. Satellite data can capture thermal anomalies, which are indicative of fires. Collect information on the fire's location, size, intensity, and direction.
2. Data Processing: Preprocess the data to remove noise and inconsistencies. Combine various datasets, such as satellite imagery and weather data, to create a comprehensive view of the fire.
3. GIS Software: Utilize GIS software like Google Earth Engine, ArcGIS, QGIS, or open-source libraries like GDAL and Fiona to create maps. Import and overlay the processed data onto a geographic map.
4. The fire mapping will focus late fire for the period will be from (August to November).

Step 5.15: Quantity of biomass lost in forest fires (Determined through remote sensing)

Data Acquisition:

1. Obtain satellite imagery data before and after the forest fire event. high-resolution imagery with spectral bands sensitive to vegetation health and biomass, such as NIR (Near Infrared) and SWIR (Shortwave Infrared) will be used.

2. Preprocessing: Preprocess the imagery to correct for atmospheric effects, geometric distortions, and radiometric calibrations.

	3. Change Detection: Perform a change detection analysis to identify areas that have been affected by the fire. This can be done by subtracting the post-fire imagery from the pre-fire imagery. 4. Vegetation Indices: Calculate vegetation indices like NDVI (Normalized Difference Vegetation Index) for both pre- and post-fire images. NDVI can help quantify the health and density of vegetation. 5. Biomass Estimation: Estimate biomass in the pre-fire image using established relationships between vegetation indices and biomass. This might involve field data collection to calibrate the relationship. 6. Biomass Loss Calculation: Subtract the estimated biomass from the pre-fire image from the biomass in the post-fire image within the areas affected by the fire. 7. Aggregate and Analyze: 8. Sum up the biomass loss values for the entire affected area to get the total biomass lost in the forest fire. 9. Accuracy Assessment: Validate results by comparing them to ground-truth data or field measurements if available. This step is crucial for ensuring the accuracy of biomass loss. **Step 5.16. Preparation of explanatory notes** An explanatory note for each forest, grassland, cropland, settlements, wetland and other land ecosystem type (classified in the land use class ecosystem map in Step 12) will be prepared based on the map attributes and the relevant field data. In the note, an appropriate name will be given to each ecosystem type based on the environmental, climatic and vegetation characteristics, and their general features will be described. **Step 5.14. Expert review and generating final forest, grassland, cropland, settlements, wetland and other land ecosystem map** The independent expert panel (identified in Step 8) will review the forest, grassland, cropland, settlements, wetland and other land ecosystem map of Eastern Province (produced in Step 12) and the corresponding explanatory notes (prepared in Step 13). They will specifically examine naming of ecosystems and their distribution in the map. The map and the explanatory note will be revised based on feedback from the expert panel, and the final forest, grassland, cropland, settlements, wetland and other land ecosystem map of Eastern Province and the related report will be produced.

4.0 SOP DATA Reliability Estimates

Reliability Estimates	Reliability estimates are only computed for trees on the forest land. The variable of interest is only the mean volume (in m^3 /ha). Ratio estimator for mean volume of forest (m^3 /ha) is computed as follows: where n = number of clusters (in forest land), xi = sum of plot sections' volumes (m3) in cluster i, pi = area of plot sections in forest in cluster I (in ha). Variance of the proportion estimates, with clusters of unequal size (variance of ratio estimator), is as follows: ∑ ∑ = · − − = · n i i i i n x px n n p x 1 2 2 ( ) 1 ( ) 1 var( ) where n = number of clusters (in forest land), xi = sum of forest plot sections' volumes (m3) in forest in cluster i, pi = sum of plot section areas in forest in cluster i (in ha), x = forest mean volume estimate (in m^3 /ha). The other estimates are computed as follows: • Standard error (m^3 /ha): SE = var(x) • Relative standard error (%): RSE = SE * 100 / x • Sampling error (95%, m^3 /ha) SAE = SE* t_value • Relative sampling error (95%, %) Rel.SAE=SAE*100/X

	Ratio estimator for mean volume of forest (m^3/ha) is computed as follows: $$\bar{x} = \frac{\sum^{n} x_i}{\sum^{n} p_i}$$ where n = number of clusters (in forest land), x_i = sum of plot sections' volumes (m^3) in cluster i, p_i = area of plot sections in forest in cluster I (in ha). Variance of the proportion estimates, with clusters of unequal size (varianc is as follows: $$\text{var}(\bar{x}) = \frac{1}{(\sum^{n} p_i)^2} \cdot \frac{n}{n-1} \cdot \sum_{i=1}^{n} (x_i - \bar{x} p_i)^2$$ where n = number of clusters (in forest land), x_i = sum of forest plot sections' volumes (m^3) in forest in cluster i, p_i = sum of plot section areas in forest in cluster i (in ha), $\bar{x}$ = forest mean volume estimate (in m^3/ha). The other estimates are computed as follows: - Standard error (m^3/ha): $SE = \sqrt{\text{var}(\bar{x})}$ - Relative standard error (%): $RSE = SE * 100 / \bar{x}$ - Sampling error (95%, m^3/ha) $SAE = SE * t\_value$ - Relative sampling error (95%, %) $Rel.\ SAE = SAE * 100 / \bar{x}$
Calculation of confidence and	**Step 2 a. Calculate the arithmetic mean using equation 1 below:**

uncertainty	$\overline{x} = \frac{1}{n}\sum_{i=1}^{i=n} x_i$,---equation 1 Where $\overline{x}$ is the mean, x is the sampled value, and n is number of sample units **Step 2 b. Calculate standard deviation provides a measurement of variation from the average value using equation 2 below:** $S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{i=n}(x_i - \overline{x})^2}$ --equation 2 Where S is the sample standard deviation, x is the sampled unit value, n is the number of sample units, and $\overline{x}$ is the arithmetic mean. This equation is applicable to simple random sampling. **Step 2 c calculate** the standard error provides the standard deviation of the mean. $SE_{\overline{x}} = \frac{s}{\sqrt{n}}$---*equation 3* Where SE is the standard error, $\overline{x}$ is the arithmetic mean, s is the sample standard deviation, and n is the number of sample units. This equation is applicable to simple random sampling. **Step 2 d: The confidence interval** gives the estimated range of values likely to include an unknown population parameter at the chosen confidence level. *CI*=*t** $SE_{\overline{x}}$---*equation 4* Where *CI* is the half width of the confidence interval at a specific confidence level or absolute error, often 95% or 90%, t is the t-value, function of the confidence level and the number of sample units, SE is the standard error, and, $\overline{x}$ is the mean.

	Step 2 e: Calculate uncertainty or relative margin of error which is estimated as a percentage, using the half width of the confidence interval as a percent of the mean. $Uncertainty = \frac{Cl}{\overline{x}}$---*equation 5* Where CI is the half width of the confidence interval at a specific confidence level, and, $\overline{x}$ is the mean. $U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots .. + U_n^2}$-----------------------------------*equation 6* Where U_{total} is the total percentage uncertainty in the product of the quantities, at the chosen *CI*, and U_n is the percentage uncertainty associated with each of the quantities. $U_{total} = \frac{\sqrt{(U_{1*}x_1)^2 + (U_{2*}x_2)^2 + \cdots ... + (U_{n*}x_n)^2}}{\lvert x_1 + x_2 + \cdots .. + x_n \rvert}$------------------------*equation 7* Where U_{total} is the total percentage uncertainty in the product of the quantities, at the chosen CI, U_n is the percentage uncertainty associated with each of the quantities, and X_i
Common Geoprocessing Classifications	**Supervised Classification: supervised classification is a technique where the algorithm is trained using labeled samples to classify pixels in an image into predefined classes. Common algorithms for this include Maximum Likelihood, Random Forest, and Support Vector Machines.** **Unsupervised Classification: Unsupervised classification pixels based on their spectral similarity. K-Means clustering and hierarchical clustering are examples of unsupervised techniques.**

5.0 SOP QUALITY ASSURANCE/QUALITY CONTROL

Those responsible for aspects of data collection and analysis should be fully trained in all aspects of the field data collection and data analyses. Standard operating procedures should be followed rigidly to ensure accurate measurement and re-measurement. It is highly recommended that a verification document be produced and filed with the field measurement and calculation documents that show that QA/QC steps have been followed.

Quality Management	
QA / QC procedures	**Sub-step Q1.** The Coordinator provides warning labels or excludes impossible transitions through logical checks built into response design. **Sub-step Q2.** The Coordinator conducts ongoing hot, cold and auxiliary data checks during data collection and conduct regular review meetings among all interpreters. Auxiliary data checks: use an external data source, such as externally created maps, to compare to the sample unit classification. Discrepancies between the two datasets can be flagged for rechecking. Confirmed differences between the two datasets can be documented to showcase why sample-based area estimation may give difference results than other data sources. Cold checks: sample units that are randomly selected from the data produced by interpreters. The decisions made by the interpreters are reviewed by the coordinator or group of interpreters meeting together. If the error by the interpreter reflects a systematic error in their interpretation, it is discussed directly with the interpreter and the affected sample units are corrected. t checks: sample units that are flagged as low confidence. These marked sample units should be further reviewed by the coordinator or group of interpreters meeting together. Once reviewed, labels that are deemed to be incorrect on these sample units should be adjusted by the interpreter.

5.1 Quality Assurance

5.1.1 Data Collection in Field:

During all data collection in the field, the crew member responsible for recording must repeat all measurements called by the crew member conducting the measurement. This is to ensure the measurement call was acknowledged and that proper number is recorded on the data sheet. In addition, all data sheets should include a 'Data recorded by' field with the name of the crew member responsible for recording data. If any confusion exists, the transcribers will know which crew member to contact.

After data is collected at each plot and before the crew leaves the plot, the crew leader shall double check to make sure that all data are correctly and completely filled. The crew leader must ensure the data recorded matches with field conditions, for instance, by verifying the number of trees recorded.

5.1.2 Data Sheet Checks:

At the end of each day all data sheets must be checked by team leaders to ensure that all the relevant information was collected. If for some reason there is some information that seems odd or is missing, mistakes can be corrected the following day. Once this is verified and potential mistakes checked, corrected data sheets shall be handed over to the person responsible for their safe keeping while the crew is still in the field. Data sheets shall be stored in a dry and safe place while in the field. After data sheets have been validated by crew leaders, the data entry process can commence.

5.1.3 Field Data Collection Hot Checks:

After the training of field crews has been completed, observations of each field crew and each crew member should be made. A lead coordinator shall observe each field crew member during data collection of a field plot to verify measurement processes and correct any errors in techniques. It is recommended that the crew chiefs switch to a different crew to ensure data collection procedures are consistent across all field crews. Any errors or misunderstandings should be explained and corrected. These types of checks should be repeated throughout the field measurement campaign to make sure incorrect measurement techniques have not started to take place.

5.1.4 Data Entry Checks:

To ensure that data is entered correctly, the person entering data (whether during fieldwork or after a return to the office) will recheck all of the data entered and compare it with the original hard copy data sheet before entering another sheet. It is advised that field crew leaders either enter the data, or participate in the data entry process. Crew leaders have a good understanding of the field sites visited, and can provide insightful assistance regarding potential unusual situations identified in data sheets. Communication between all personnel involved in measuring and analyzing data should be used to resolve any apparent anomalies before final analysis of the monitoring data can be completed. If there are any problems with the plot data (that cannot be resolved), the plot should not be used in the analysis.

5.2 Quality Control

5.2.1 Field Measurement Error Estimation

A second type of field check is used to quantify the amount of error due to field measurement techniques. To implement this type of check, a complete re-measurement of a number of plots by people other than the original field crews is performed. This auditing crew should be experienced in forest measurement and highly attentive to detail. A total of 10% of plots (or clusters if clustered plots are used) should be randomly or systematically chosen to be re-measured. Where clustered plots are used, all plots within a selected Cluster shall be measured. All trees shall be re-measured in each plot. Field crews taking measurements should not be aware of which plots will be re-measured whenever possible.

After re-measurement, data analysis is conducted and biomass estimates are compared with estimates from the original data. Any errors discovered could be expressed as a percentage of all plots that have been rechecked to provide an estimate of the measurement error.

For all the verified plots:

$$\text{Measurement Error (\%)} = \frac{\text{(t C/ha of Measured plot} - \text{t C/ha of re-measured Plot)}}{\text{T C/ha of re-measured plot}} \times 100$$

5.2.2 Data Entry Quality Control Check:

After all data has been entered into computer file(s), a random check shall be conducted. Sheets shall be selected randomly for re-checks and compared with data entered. Ten percent of all data sheets shall be checked for consistency and accuracy in data entry. Other techniques such as data sorting and verification of resulting estimates shall be employed to ensure data entered properly corresponds to field sites visited. Personnel experienced in data entry and analysis will be able to identify errors especially oddly large or small numbers. Errors can be reduced if the entered data is reviewed using expert judgment and, if necessary, through comparison with independent data.

5.2.3 QA/QC of Laboratory Measurements

Standard operating procedures (SOPs) should be created and rigorously followed for each part of all laboratory analyses. All instruments should be calibrated.

For example, all combustion instruments for measuring total C or C forms should be calibrated using commercially-available certified C standards. SOPs should include steps to calibrate and check analyses. Blanks can be analyzed, or analytical runs can include a check sample of known C concentration. One standard per batch/run should be included in the samples sent to a remote lab as an additional check of the quality of the instruments and lab procedures.

All balances for measuring dry weights should be calibrated against known weights. Where possible, 10-20
% of samples could be reanalyzed/reweighed to produce an error estimate.

6.0 SOP DATA STORAGE AND ARCHIVING

Field equipment
Field logbook/ electronic field logbook
Laptop computer
Desktop computer Connection to network server
Scanner
Database

This SOP describes the methods for storing and archiving data in a simple yet safe and retractable way, so data can be accessed whenever necessary. Data storage and archiving is a very important and final component of the data collection process. The basic framework involving data storage and archiving follows.

6.1 Data Storage in the Field

In the field one person is responsible for storing and keeping the field data sheets; this person can also be the person who also validates the data on the sheets and is one of the team leaders. If the data entry process is being done or started in the field, these sheets will be used after which they must be returned to the person responsible for their safe keeping. These sheets are stored in a dry and safe place where they cannot be tampered with until they are transported to the office.

6.2 Data Storage in the Office

In the office, all original field data sheets shall be scanned and compiled into a document to be stored electronically. This avoids any changes to be made to the original sheets.

6.3 Hard Copy

The original data sheets are photocopied and are kept in a separate location. The data sheets are placed in a special jacket folder in the filing cabinet with the location name and date written on the label. Inside of these jackets, there are folders with the different types of data collected (Biomass, Logging, Skid trails, Roads and Decks, Regrowth, Wood Density etc.). After all data has been entered into a digital format and SOP QA/QC completed, the two sets of data sheets are then stored in secure fireproof filing cabinets in two separate locations.

6.4 Soft Copy

The scanned data sheets are stored on a computer in the office, along with all tools with the entered data, including data entered in the field laptop. These data files are backed up on a server. Folders containing data and folders containing tools should be properly named and adequately organized. All digital data collected and compiled (photos, proposal and report for exercise) are also stored in the archive file on both the desktop in the office and on the server. On the server there are a few folders in which all data are placed as follows:

1. '*Field Data*', in which sub folders are created and are named the same way (Location) as the hard copy folder so as to have a uniform filing system. In each sub folder there are two folders; pictures and scanned data sheets in which the respective information are placed;

2. '*Data Analysis*' in which all completed tools are placed after the data entry has been completed;
3. '*Template*' in which all tool templates and field data sheets used in the data analysis are placed;
4. '*Documents*' in which all documents related to the project are placed; and
5. '*Field Proposal & Report'* in which all field exercise proposals and report are placed.

6.5 Procedure for Data File Backup

Any file(s) that is updated during the data analysis will be backed up to a network server. This back up will be done daily on the office computer(s), and at the end of every week they must be saved on an external hard drive and the folder on the server which is specifically designated for this data storage.

6.6 Procedure for Compiling and Managing Field Log Book or Electronic Log Book

This log book will be both of an electronic form and of the traditional book keeping format (a book). Both log forms will be updated simultaneously and twice for each field venture, before and after each trip. Log books will be used for recording the logistics of the field exercise, and providing explanation about field campaigns (e.g. date of departure to the field and date of returning, number of plots, location, field crew, challenges etc.). Each field campaign will be given a unique reference number and each report will also be given a reference number related to that of the campaign. This is to facilitate cross referencing processes.

Upon returning to the office after field records are entered, the log books will be stored in a secure filing cabinet or placed on the network server via desktop computers respectively, after being updated. Upon the completion of field reports of which each report will be given a unique reference number, the log books will be revisited and the report number will be inserted for future references.

It is important to restrict access to log books and information only to users, as they alone are responsible for making changes.

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Ministry of Green Economy and Environment

Zambia Integrated Forest Landscape Project

Improving lives through Sustainable Management of Natural Resources

The Zambia Integrated Forest Landscape Project is a Government initiative which provides support to rural communities in the Eastern Province to allow them to better manage the resources of their landscapes so as to reduce deforestation and unsustainable agricultural expansion; enhance benefits they receive from forestry, agriculture, and wildlife; and reduce their vulnerability to climate change.

Simultaneously the project is creating the enabling environment for emission reduction purchases to be done through the subsequent phase - the Zambia Eastern Province Jurisdictional Sustainable Landscape Programme (EP-JSLP).

The ZIFL- Project is a product of cooperation between the Government of Zambia, the World Bank & partners.

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