VCS MODULE VMD0019

METHODS TO PROJECT FUTURE CONDITIONS

Version 1.0

16 November 2012

Sectoral Scope 14

Document Prepared by: The Earth Partners LLC.

Table of Contents

1 SOURCES

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

2 SUMMARY DESCRIPTION OF THE MODULE

Preparation of ex-ante projections of GHG pools and emissions under the baseline and project scenarios requires making informed estimates of future values of a wide range of variables. Some examples of the sorts of variables that might need to be projected include:

- Specific pools or emissions. For example, it might be necessary to estimate the future amount of carbon stored in the soil pool under the baseline scenario, using a soil carbon model.
- Market factors which influence pools or emissions. For example, it might be necessary to project future demand for a particular commodity when assessing the rate at which production of that commodity would grow within the project area.
- Human and cultural factors which influence pools or emissions. For example, it might be necessary to project what a particular farmer would do on a property in the future, based on that farmer's needs and desires.
- Biological and related factors which influence pools or emissions. For instance, it might be necessary to project the impact that global warming-related weather changes will have on frequency of fires in rangeland.

The module provides a step by step approach to assessing the key factors that drive change in the variable in question, and it provides a suite of methods and approaches for projecting future conditions, as well as decision criteria for choosing the correct method, for the variable in question.

3 DEFINITIONS

Baseline:	The total amount of carbon within the project area in absence of the project.
Baseline Scenario:	The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project.
Conservative:	Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables.
Controlled:	Change in a variable is under the control of the project proponent.
Ex-ante:	Before the fact. Projection of values or conditions in the future.
Ex-post:	After the fact. Estimation of values or conditions in the present or past.
Leakage Zone:	Zone in which the leakage is expected to occur and therefore needs to be monitored.
Location Specific:	Variations in the value of a variable are tied to a specific location, and typically that the value of the variable changes across the landscape.
Location Specific Approach:	An approach to predicting the future value of a variable which takes account of changes across the landscape, and predicts different values of the variable in different places.

Planned: Changes in the value of the variable are under the control of identified agents who are independent of the project proponent.

Process Specific: Variations in the value of the variable are associated with specific actions, ongoing events, or global conditions, rather than with specific locations.

Project Area: The area or areas of land on which the project proponent will undertake the project activities.

Project Scenario: The actions and events which are expected to occur as a result of implementing the project.

Proxy: See *VCS Program Definitions.*

Reference Condition: A condition of the ecosystem which is believed to have existed at some time, and which reasonably approximates the intended condition which will exist if the project is successful.

Reference Region/Area: An area of land outside of the project area, but which displays similar conditions to some or all of the area within the project area, and which can therefore be analyzed to understand processes which have or may occur within the project area.

Stratification: The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people.

Stratified Approach: Projection of future conditions based on the division of the area into strata, and the projection of a single value of the variable for each stratum at each time.

Systemic: A variable whose future value depends primarily on one or more causes not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems (economic, ecological, etc.) outside of local control. For instance, cattle grazing intensities in an area may go down if there is a large drop in the price of beef.

Value Class: A range of the value of a variable which will be treated as a single set, for the purposes of analysis. For instance, all areas with forest cover between 70% and 100% might be treated as a single value class, and analyzed on that basis.

4 APPLICABILITY CONDITIONS

None

5 PROCEDURES

Introduction

The module is designed to allow the projection of future values of a variable, *X*, which has been identified as having a significant influence on the future GHG impacts of emissions or changes in pools under the baseline or project scenario. This variable will fall into one of two types:

a) The variable is location specific. That is to say, the variable is associated with the land and varies across the landscape. For instance, carbon in living biomass and soil carbon are both location specific variables. Location specific variables can often be estimated and projected for a specific moment in time. For instance, the total biomass or the total soil carbon at a given moment in time on a given area can be estimated using sampling techniques.
b) The variable is process specific. Process specific variables are associated with specific actions, ongoing events, or global conditions, rather than with specific locations. For instance, emissions from power equipment are ongoing events, and therefore process specific. Process specific variables are often, although not always, estimated or projected for a time span. For instance, emissions from fuel use are typically estimated over a time span such as a year. Thus while one could estimate soil carbon in a given area at a point in time, typically one would estimate fuel use over a period of time.

Either of these types of variables can fall into one of 3 categories:

a) *Controlled*. The future value of the variable will primarily be a result of actions under the control of the project proponent. For instance, the project proponent intends to reduce the cattle grazing intensity by 25% on land they control.
b) *Planned*. The future value of the variable will primarily be the result of planned or projected actions by one or a few parties acting independently of the project proponent. For instance, farmers in the area have stated that they plan to reduce the cattle grazing intensity, but the project proponent cannot force this to happen.
c) *Systemic*. The future value of the variable depends primarily on one or more conditions whose future value is not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems outside of local control. For instance, cattle grazing intensities in the area may go down if there is a large drop in the price of beef.

These combinations of variable type and category gives rise to four different classes of variables:

1) Controlled variable, either location or process specific
2) Planned variable, either location or process specific
3) Systemic variable, location specific
4) Systemic variable, process specific

In all cases, Steps 1 through 5 must be used to determine the class of variable being projected. Classes will then require different sequences of steps to project the future conditions of the variable, as follows:

1) Controlled variable, either location or process specific
   - Step 10 to determine the limits to the possible values of the variable
   - Step 11 to verify the planned actions of the project proponent
2) Planned variable, either location or process specific
   - Step 10 to determine the limits to the possible values of the variable
   - Step 12 to verify the planned actions of the agents impacting the value of the variable
3) Systemic variable, location specific
   - Step 7 to determine the historic trends in the value of the variable
   - Step 8 to determine the agents, causes and drivers impacting the value of the variable
   - Step 9 to re-examine the category of the variable. It is possible that during this step variables will be found to be controlled or planned, even though they were initially assessed as

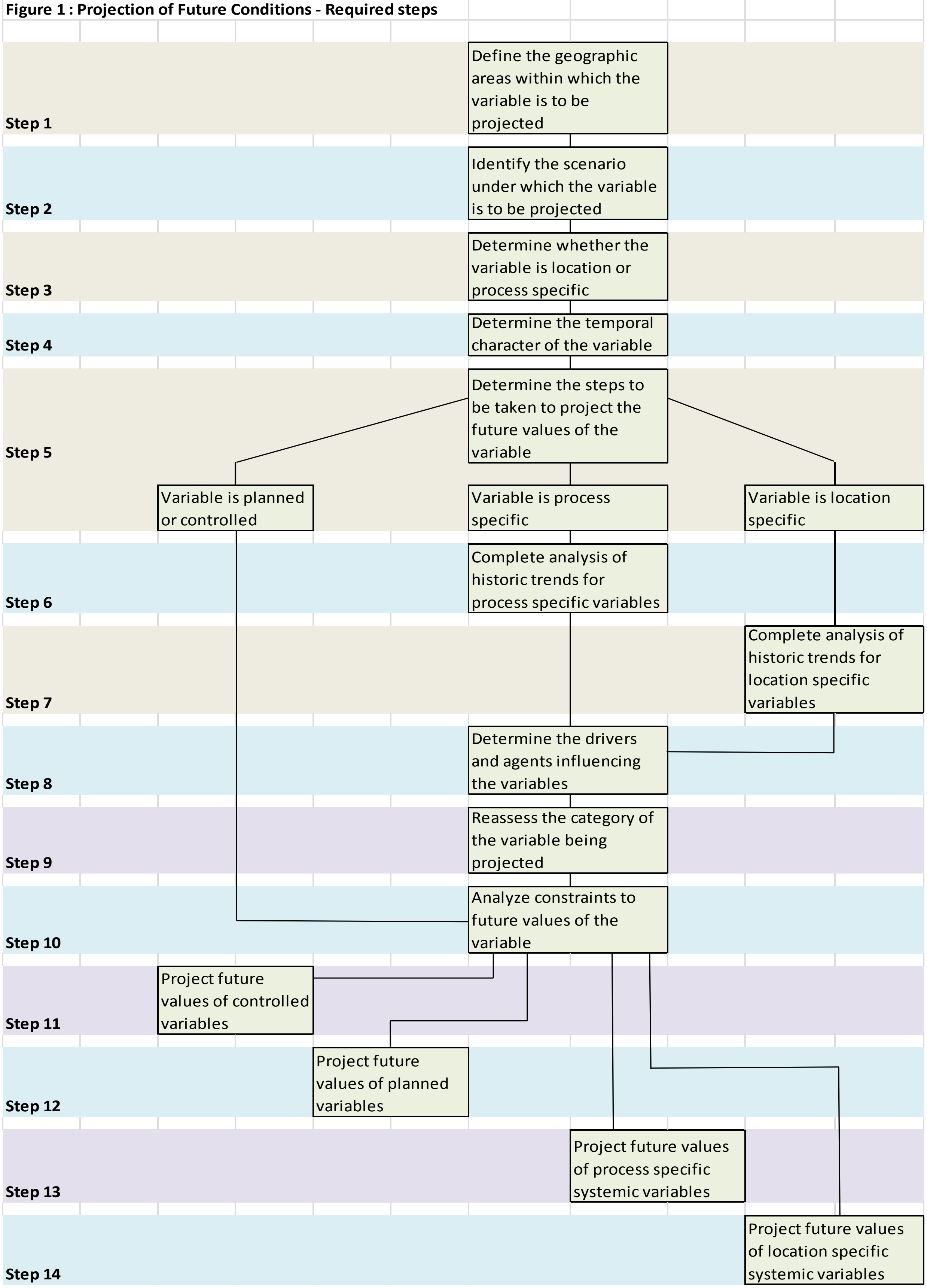
systemic. In that case, follow the sequence of steps for either controlled or planned variables. Step 10, to determine the limits to the possible values of the variable

- Step 14 to project the future values of the variable

4) Systemic variable, process specific
   - Step 6 to determine the historic trends in the value of the variable
   - Step 8 to determine the agents, causes and drivers impacting the value of the variable
   - Step 9 to re-examine the category of the variable. It is possible that during this step variables will be found to be controlled or planned, even though they were initially assessed as systemic. In that case, follow the sequence of steps for either controlled or planned variables
   - Step 10 to determine the limits to the possible values of the variable
   - Step 13 to project the future values of the variable

The sequences of steps required are shown graphically in Figure 1 below:

Figure 1 : Projection of Future Conditions - Required steps



Step 1: Define the geographic area(s) within which the variable *X* is to be projected

Goal: Determine the geographic area(s) within which or for which changes in the variable *X* are to be determined, and map these areas to the standards required for mapping of the project area

Methods and guidance: Identify the area within which the variable will be projected. This may be a stratum, the project area, or the project area plus a reference region. Projection may also be required within a leakage zone if the leakage zone method is being used to determine leakage (Step 3 of module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*).

In some cases, the projection of location specific variables may not occur over the whole project area, but on a stratum by stratum basis. Where this is the case, the defined areas will be the strata, and each stratum will be analyzed and projected separately. However, much of the work in projecting future conditions will be the same for all of the strata, and the analyses may be conducted in parallel, noting the differences between the strata.

Step 2: Identify the scenario under which the variable *X* is to be projected

Goal: Determine whether the variable is to be projected under the baseline scenario or the project scenario, or both, and document the results

Step 3: Determine the type and category of the variable being projected

Goal: Determine whether the variable is location specific or process specific, and whether the variable is controlled, planned or systemic, and document the reasoning and evidence for each of these determinations.

Methods and guidance: Determine whether the variable is location specific or process specific. Note that some variables can bear some characteristics of both types. For instance, cattle populations may vary across the landscape, but are typically determined by the rancher, based on their knowledge of the carrying capacity of the land as a whole, rather than specific portions of it. In this case, cattle populations would be a process specific variable, since the primary determinant of the variable is not the characteristics of a specific location, but the decisions of the rancher.

On the other hand, conversion of an area of land from forest to pasture by settlers will typically be location specific because, although the settlers are making the decision to clear, they will typically decide to clear the best land first – thus the primary determining factor in whether or not a specific area of land is cleared will be a characteristic of the location – in this case the quality of the land.

In general, if the percentage change of the variable in question under the scenario being examined occurs at different rates within the area, and this variability is significantly determined by a variability of the land within the area being examined, the variable is considered location specific.

If the percentage change of the variable in question under the scenario being examined occurs primarily as a result of decisions or processes which are not dependent on the characteristic of a specific location, the variable is process specific.

Either of these types of variables falls into one of three categories. Determine which category the variable falls into, based on the following guidance:

- *Controlled*. The future value of the variable is controlled if changes in the variable will primarily be a result of actions under the control of the project proponent. For instance, the project proponent intends to reduce the cattle grazing intensity by 25% on land they control.
- *Planned*. The future value of the variable is planned if changes in the variable will primarily be the result of planned or projected actions by one or a few parties acting independently of the project proponent. For instance, farmers in the area have stated that they plan to reduce the cattle grazing intensity, but the project proponent cannot force this to happen.
- *Systemic*. The future value of the variable is systemic if changes in the variable depend primarily on one or more conditions whose future value is not subject to knowable plans, typically because they involve or depend on the actions and influences of unknown actors and/or large scale systems outside of local control. For instance, cattle grazing intensities in the area may go down if there is a large drop in the price of beef.

Step 4: Temporal character of the variable

Goal: Determine the temporal character of the variable, and document the reasons for the determination.

Methods and guidance: The temporal character of the variable is defined by the time period over which the variable has existed and the reasons for it existing. Variables are:

- *Inherent.* The variable is an inherent characteristic of the area or the natural processes affecting the area, and therefore the variable existed without human intervention or existed as a result of human actions over a very long period of time in the past (for instance, traditional landscape burning by indigenous peoples).
- *Caused.* The variable is a characteristic which arose as a result of some specific human action at a known time, and therefore has a clear start (for instance, commencement of grazing of domestic sheep in an area).
- *Projected*. The variable is a characteristic which will arise as a result of projected human activities at some time in the future under the baseline scenario (for instance, humans caused deforestation in an area which currently has never been deforested).
- *Intended*. The variable is a characteristic which will arise as a result of the project activities under the project scenario (for instance, emissions from project activities).

If a variable is projected, and is also a systemic variable and location specific, reference areas should be found within which the characteristics and processes of change associated with the variable already exist. For instance, an area within which human caused deforestation is already occurring. If no such area can be identified, a modeled approach must be used to project the future values of the variable in Step 14.

Step 5: Determination of the steps to be taken to project the future value of the variable

Goal: Based on the previous steps, determine and document the degree of certainty of the type, category and temporal character of the variable, and based on this determination lay out the series of steps which will be undertaken to project the future values of the variable.

Methods and guidance: In order to demonstrate a high degree of certainty in the determinations of the type, category and temporal character of the variable, the project proponent must be able to demonstrate and document that under current conditions the statement is true, and that anticipated future changes in conditions are unlikely to make it untrue. For instance, if the variable in question is cattle grazing densities on land owned and managed by the project proponent, it is true that at the current time the project proponent controls the amount of cattle grazing on that land. If it is also true that there is very low likelihood that the project proponent will surrender ownership or management of the land in the future, then it can be stated that with a high degree of certainty cattle grazing densities are a controlled variable.

Based on this determination, for the variable in question:

If there is a high degree of certainty that the future change in the variable under the scenario in question will be determined by the project proponent, or by agents under his or her control, the variable is controlled. Go to Steps 10 and 11. If not, then:

If there is a high degree of certainty that the future change in the variable under the scenario in question will be determined by a known group of agents independent of the project proponent, the variable is planned. Go to Steps 10 and 12. If not, then:

If the variable is process specific, go to Step 6. If the variable is location specific, go to Step 7.

Note that in some cases stratification of the project area may need to take these distinctions into account. For instance, if the project area consists of two pieces of land, including an area of land which may be homesteaded and converted in part to cropland by settlers who have not yet arrived, and an area of land owned by a single family, who plan to convert it into cropland, then the project area should be stratified with the first area being analyzed as systemic and location specific and the second area analyzed as planned.

Step 6: Analysis of historic trends for process specific variables

Goal: Gather, document and analyze the available data on historic trends in the value of the process specific variable. Based on this work, produce a summary of the historic trends which indicates both the results of the analysis and any uncertainties resulting from data gaps or low quality data.

Methods and guidance: Initially, determine whether or not there is any historical occurrence of the variable in the analysis area. If the variable in question had no value prior to the current time, or currently has no value (for instance if the variable is project emissions from the use of power equipment, assessed at a time prior to the commencement of the project), skip this step and go to Step 13. If not:

Gather and document all available information on historic changes and values of process specific variables. Rate the reliability of the information, and note any information gaps which may exist. Information should be drawn from any available documented sources. These may include:

- Local, regional or national government mapping, statistics and records
- Land title records
- Published and unpublished research
- Local records contained in newspapers, NGO and business records
- Economic data

Where appropriate, information from oral sources should also be collected, as in many cases, information from oral sources may be the only available information, or may substantially increase the available body of information.

Based on the information gathered, determine and document the most likely historic trajectory of change in the variable over a period of at least 10 years. Assess and document the degree and causes of uncertainty associated with this work.

Step 7: Analysis of historic trends for location specific variables[1]

Goal: Analyze historic trends for location specific variables, using the appropriate methods given below. Document each of the steps taken, the data sources, methods of analysis, and degree and potential sources of uncertainty.

Methods and Guidance: For the purposes of Step 7, location specific variables are categorized into three types:

- *Assessable through remote sensing*. For instance, if the variable is forest cover, it can generally be directly assessed from remote sensing, both satellite, as well as aerial photography for periods prior to the availability of satellite based sensing.
- *Partly assessable through remote sensing using a proxy*. Some variables, such as soil carbon, are not directly assessable through remote sensing, however, in a given ecosystem, soil carbon may be reasonably correlated with vegetation cover types which are detectable through remote sensing.
- *Not assessable through remote sensing*. While many variables can be at least partly assessed using proxies and remote sensing, some variables may not be detectable using remote sensing. For instance, in some ecosystems soil texture may not produce vegetation or other changes detectable by remote sensing.

For each of the three types, a specific set of steps must be followed, as follows:

- Assessable through remote sensing – Steps 7a and 7c
- Partly assessable through remote sensing using a proxy - Steps 7a, 7b and 7c
- Not assessable through remote sensing – Step 7a

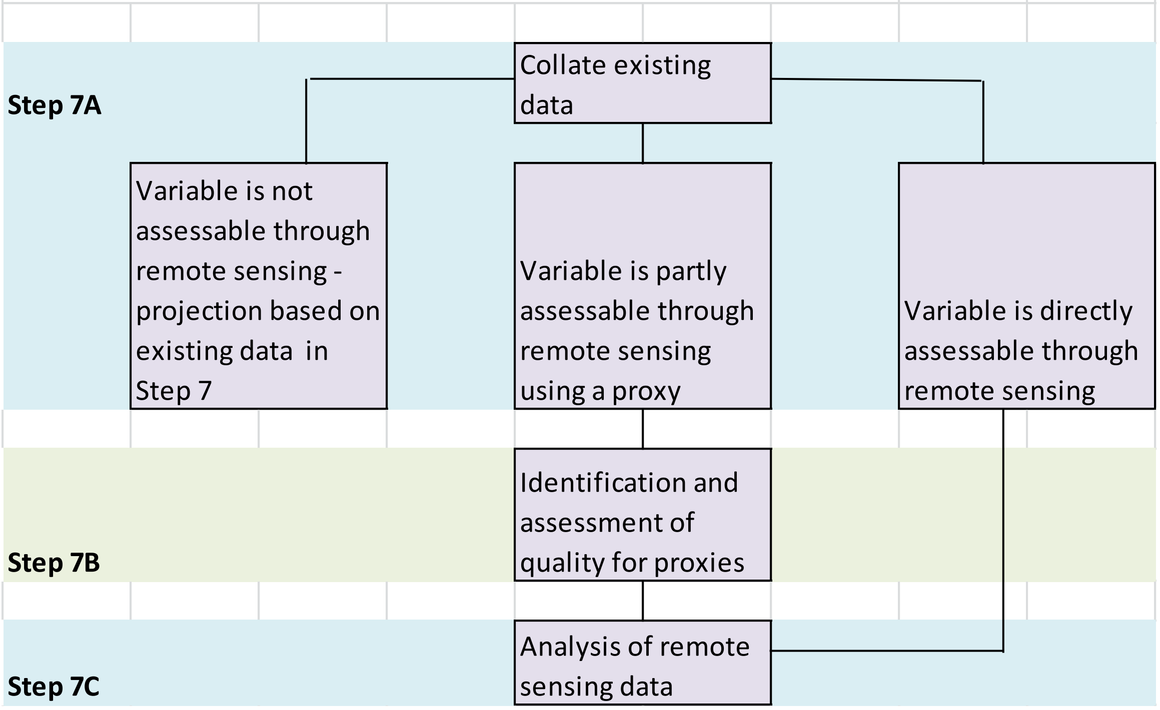
Where assessment through remote sensing is to be done, either directly or through a proxy, it should be done for both the project area and the reference region if projection is being undertaken as part of Task 2, the baseline. Assessing the wider area will give more information on trends in the value of the variable over time.

Where a leakage zone is being used to monitor leakage, the leakage zone must also be assessed during this phase.

The sub-steps in Step 7 are shown in Figure 2 below.

[1] Derived from Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation, author Lucio Pedroni, now consolidated in VCS Methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

Figure 2 : Analysis of historic trends for location specific variables



Step 7a Collation of existing data

Collation and analysis of existing data must be undertaken as described for Step 6. Particular attention should be paid to existing spatially specific data such as maps, historic studies and ground level photography.

Note that if the variable in question is assessable or partly assessable through remote sensing, it is possible that existing work has already been done for the area to classify it for the variable in question, or the proxy variable being used. If this classification can be shown to have been of good quality, using consistent methods for multiple time points, it may be unnecessary to undertake further remote sensing interpretation. If such data exists for only one time point, and the methods used to produce the data are known, it may be possible to undertake assessment of other time points following the steps below using the same methods, and thus reduce the amount of remote sensing interpretation required.

It is also possible that high quality time series data derived from direct sampling and measurement of the variable in question exists for the area from other sources – for instance repeat soil surveys associated with management. If data of this type is available, it should form the primary source for determining the historic trends for the variables. In this case, depending on the degree of geographic coverage of the existing data, project proponents may optionally conduct the remote sensing analysis described in Step 7c below as a back-up to the existing data, or to extrapolate it to areas not covered by the existing data.

Step 7b: Identification and assessment of quality for proxies

Proxies are features visible with remote sensing that provide indications of the status of features which are not visible with remote sensing. Proxies should be identified from one of the following two sources:

- Existing scientific literature on processes and relationships within landscapes, particularly landscapes with similar ecosystems and processes to the area being examined.

- Correlation between characteristics visible in current remote sensing images, and data on the status of the variable in question, drawn from field surveys undertaken to the standards laid out for field surveys in this methodology, or to similar standards.

Proxies identified from the scientific literature must be verified onsite using the second approach. Based on the correlation of field surveys and current remote sensing images, the project proponent must document:

- The nature of the characteristics detectable in the remote sensing images which correlate with differences in the state of the variable *X* on the ground.
- The apparent degree of correlation between the two, based on statistical analysis of the relationship.
- The theoretical basis for the proposed correlation. In other words, the project proponent must offer a reasonable explanation of why the correlation between the proxy and the variable in question exists.

Step 7c: Analysis of remote sensing data

The goal of the analysis of remote sensing data is to produce a time series of assessments of the value and variation of the variable *X*, or a proxy, across the area. This data on historical values and geographic correlations of the variable will be used later in this module to assist in the projection of future values of the variable on a location specific basis.

In order to maximize the value of this step, the following process must be followed:

Step 7c.1: Identification of the probable rate of change and historic period of change

Depending on the specific variable in question, the rates of change, and period over which the change has occurred, may vary substantially. The project proponent must determine and document the best information or estimates that they have available on:

- When the change from the reference condition began, if a reference condition exists for the variable. (See Step 8a below for a discussion of the reference condition.)
- How long the variable took to reach a state approximately like that currently existing, for a specific location.
- Whether the variable has now reached a relatively stable condition at any place within the area, or whether significant change is still occurring everywhere.

Based on this data, the project proponent must determine what the time period is over which they will need to analyze the value of the variable to be able to determine reasonably the rates and trajectory of change for a given location, and for the area as a whole. This period does not need to encompass the whole history of change in the variable, but should be sufficiently large to encompass a significant portion of the history of change. The time period may also be significantly constrained by the availability of remote sensing imagery, based on the work undertaken in 7c.2 below.

Step 7c.2: Location of the available remote sensing resources

Identify the time span over which there are available remote sensing images. These could include satellite images and aerial photography. It is also possible in some cases that this could include ground-based photography where enough location identifiers are present to allow geo-referencing of some features.

If the available resources will not adequately capture a meaningful proportion of the period of change defined in 7c.1 above, go to Step 8. Otherwise, select specific images which cover the time period. Ideally images will be relatively evenly spaced. A minimum of three images from different times (beginning and middle of the time period, and a current image) must be used if available. In many instances, using 4 images may be useful, allowing more scope for truthing of extrapolated rates and locations of change in the variable.

Step 7c.3: Pre-processing

Pre-processing typically includes:

a) Geometric corrections to ensure that images in a time series correlate properly to each other and to other Geographical Information System (GIS) maps used in the analysis (i.e. for post-classification stratification). The average location error between two images should be < 1 pixel, to allow utilization of automated change detection systems.

b) Cloud and shadow removal using additional sources of data (e.g. Radar, aerial photographs, field-surveys). In general images with more than 10% cloud cover within the area being analyzed should have cloud and shadow removal done, or should be discarded.[2]

c) Radiometric corrections may be necessary (depending on the change-detection technique used) to ensure that similar objects have the same spectral response in multi-temporal datasets.

d) Reduction of haze, as needed.

See Chapter 3 of the GOFC-GOLD sourcebook on RED (Brown *et al.,* 2007) or consult experts and literature for further guidance on pre-processing techniques.

Duly record all pre-processing steps for later reporting.

Step 7c.4: Interpretation and classification

Two main categories of change detection exist and can be used (see IPCC 2006 GL AFOLU, Chapter 3A.2.4):

a) Post-classification change detection: Two maps are generated for two different time points and then compared to detect changes in the variable being examined. The techniques are straightforward but are also sensitive to inconsistencies in interpretation and classification of the value of the variable.

b) Pre-classification change detection: These are more sophisticated approaches to change detection. They also require more pre-processing of the data (i.e. radiometric corrections). The basic approach is to compare by statistical methods the spectral response of the ground using two data sets acquired at different dates to detect the locations where a change has occurred and then to allocate different patterns of spectral change to specific types of change in the variable. This approach is less sensitive to

[2] Derived from Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation, author Lucio Pedroni, now consolidated in VCS methodology VM0015 Methodology for Avoided Unplanned Deforestation

interpretation inconsistencies but the methods involved are less straightforward and require access to the original unclassified remotely sensed data.

As several methods are available to derive maps of changes in the variables from multi-temporal data sets, no specific method is recommended here. As general guidance:

- Automated classification methods are often preferred because the interpretation is more efficient and repeatable than a visual interpretation. However, automated classification should be carefully examined for potential systematic errors. If such errors are not correctable, manual classification may be required. Particular attention should be paid to possible errors caused by combinations of terrain and time of day causing differences in spectrum or brightness which are not correlated with any change on the ground.
- Independent interpretation of multi-temporal images should be avoided (but is not forbidden).
- Interpretation is usually more accurate when it focuses on change detection with interdependent assessment of two multi-temporal images together. A technique that may be effective is image segmentation followed by supervised object classification.
- Minimum mapping unit should be determined based on the resolution of the images.
- See Chapter 3 of the GOFC-GOLD sourcebook on RED (GOFC-GOLD, 2009)[3] or consult experts and literature for further guidance on methods to analyze change in variables using remotely sensed data.
- Typically, remote sensing results should be stated in terms of value classes rather than values. For instance, if the variable being assessed is ground cover, cover classes should be defined. (For instance, 80% to 100% cover, 50% to 80% cover, etc.) The value classes defined should be classes which are expected to be reliably distinguished from the remote sensing.

Duly record all interpretation and classification steps for later reporting.

Step 7c.5: Post-processing

Post-processing includes the use of non-spectral data to further assess differences in the variable across time and across the landscape. Post-classification stratification can be performed efficiently using GIS.

Current remote sensing technology may be unable to accurately discriminate certain changes in the variable. Where there is likely to be a wide variation in the value of the variable that has not been picked up from the remote sensing work, other data sources must be integrated into the GIS at this point, such as:

- Biophysical criteria (e.g. climate or ecological zone, soil and vegetation type, elevation, rainfall and aspect);
- Disturbance indicators (e.g. vicinity to roads and concession areas);

[3] GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,49 (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada)

- Land management categories (e.g. protected forest and indigenous reserve); and/or,
- Other criteria relevant to differences in the variable.

Duly record all post-processing steps for later reporting.

At the end of Step 7c.5, the following products must be prepared:

a) A map for each date analyzed, showing the estimated values of the variable across the area.

b) A change map, showing the change in the value or value class of the variable from each date to the next date analyzed for each point or area analyzed. Many projects will have some level of no-data areas because of cloud-cover. In this case, change rates must be calculated for each time step based only on areas that were not cloud-obscured in either date in question.

c) A change matrix for each change map. The matrix will be a table showing, for each classification of the variable on the first date, how many hectares were in that classification, what classifications those hectares fell into on the second date.

Step 7c.6: Map accuracy assessment

Project proponents must demonstrate the accuracy of the maps through a verifiable accuracy assessment. The accuracy assessment should be demonstrated with the following procedure.

The accuracy assessment should be undertaken by comparing the value or value class of the variable as mapped with the actual value or value class of the variable as determined from other sources. This is most likely to be undertaken on the mapping of the current conditions, where ground based work can be undertaken to confirm the value of the variable. A number of sample points on the map and their corresponding correct classification (as determined by ground-surveys or interpretation of higher resolution data) should be assessed.

The minimum overall accuracy of the map assessed should be 90%. In other words, not less than 90% of the randomly selected sample points should be correctly classified. Furthermore, examination of the incorrectly classified sample points should not reveal a systematic error with an identifiable cause. For instance, if most of the points incorrectly classified as grassland were actually shrubland, and the error resulted from topographically caused changes in spectrum or luminosity, the classification work should be redone to correct for this systematic error.

Where the mapping shows a number of different value classes for the variable (for instance, 100% ground cover, 70% ground cover, etc.), the minimum classification accuracy for each of these value classes on the map should be 80%. If the classification of a class is lower than 80%, consider merging the class with other classes[4]; Thus for instance if ground cover is being classified and if the 100% cover and 70% cover classes are difficult to distinguish and often misclassified, consider combining the two categories. Again, in this case, where random checking shows systematic error with an identifiable cause, the work should be redone.

Both commission errors (false detection of a value or value class, such as “deforestation”) and omission errors (non-detection of actual value or value class, such as “deforestation”) should be estimated and reported.

[4] The trade-off of merging classes is that carbon estimates will be subject to a higher degree of variability.

The “goodness of fit” measure should include an assessment of the correct estimation of the quantity of change and an assessment of the correct location of change. To measure the degree to which a simulated map agrees with a reality map with respect to both location and quantity of pixels, Kappa-for-location and Kappa-for-quantity can be used, respectively (Pontius, 2000).

Where the assessment of map accuracy requires merging or eliminating value classes to achieve the required map accuracy, the definitions of the value classes must be adjusted accordingly. The final maps and the value class definitions must be consistent.

Step 7c.7: Preparation of a remote sensing method as an annex to the project description

Remote sensing analysis is an evolving field and will be performed several times during the project term. A consistent time-series of data must emerge from this process.

To achieve a consistent time-series, the risk of introducing artifacts from method change must be minimized. For this reason, the detailed methodological procedures used in pre-processing, classification, post classification processing, and accuracy assessment of the remotely sensed data, must be carefully documented in an annex to the project description. In particular, the following information must be documented:

a) Data sources and pre-processing: Type, resolution, source and acquisition date of the remotely sensed data (and other data) used; geometric, radiometric and other corrections performed, if any; spectral bands and indexes used (such as NDVI); projection and parameters used to geo-reference the images; error estimate of the geometric correction; software and software version used to perform pre-processing tasks; etc.

b) Data classification: Definition of the value classes; classification approach and classification algorithms; coordinates and description of the ground-truthing data collected for training purposes; ancillary data used in the classification, if any; software and software version used to perform the classification; additional spatial data and analysis used for post-classification analysis, including class subdivisions using non-spectral criteria, if any; etc.

c) Classification accuracy assessment: Accuracy assessment technique used; coordinates and description of the ground-truth or high resolution data collected for classification accuracy assessment; post-processing decisions made based on the preliminary classification accuracy assessment, if any; and final classification accuracy assessment.

d) Method changes: If in subsequent monitoring periods changes will be made to the original remote sensing method:

- Each change and its justification must be explained and recorded; and
- When methods change, at the moment of change, the entire time-series of past estimates that is needed to update the baseline must be recalculated using the new method.

Step 8: Determine the drivers and agents influencing the variable

Goal: Determine the drivers and agents influencing the variable. Document the steps taken, data sources used, and degree and sources of potential uncertainty.

Methods and guidance: This step is not required for planned or controlled variables, since we know who is driving change in the variables in those cases, and can enquire directly as to what they are planning and why. This is only required for systematic variables.

For systemic variables, understanding why the variable *X* has the values it does, what is driving changes in the variable *X* (drivers and underlying causes), and "who" is acting in ways that change the variable *X* (the "agents") is necessary for two main reasons: (i) Estimating the quantity and location of future change in the variable *X*; and (ii) Designing effective measures to change the future trajectory of *X*, if this is one of the project goals (for instance, increasing soil carbon). Understanding the drivers, causes and agents may also be critical to designing project activities and leakage prevention measures.

This analysis must be performed through the following six sub-steps[5]:

a) Identification of the reference condition of the variable

b) Identification of agents of change in the variable;

c) Identification of drivers of change in the variable;

d) Identification of underlying causes;

e) Analysis of chain of events leading to changes in the variable;

f) Conclusion

Step 8a: Identification of the reference condition of the variable

This step is to be undertaken only for location specific variables. If the variable in question is process specific, proceed to Step 8b.

For location specific variables, identify the reference condition, which is often the expected condition of the ecosystem after the completion of the project. The reference condition should be similar to some condition which existed at a prior time, before ecosystem degradation occurred, and which serves to define the target which the project hopes to achieve. For instance, if the project is expected to improve soil carbon through the removal of invasive trees and non-native species, and the re-establishment of native grasslands, the reference condition is probably the condition of the site prior to invasion of woody and non-native plants, and the degradation of the grasslands. Identify as well a reference time, which is the time in the past at which the reference condition existed. The project proponent must document:

- When in the past the project area was in a condition similar to the desired condition.
- What the project area looked like at that time, in terms of species composition, soil characteristics, ecosystem processes, etc.

This reference time may be a time prior to the commencement of intensive management by humans, or under some earlier management regime, or at some time in the past under the current management regime.

Document what evidence there is to support the selection of the reference time, and what evidence there is of the condition of the project area at that time.

Global change may make identification of reference conditions and reference times within the area very difficult (e.g., if changes in precipitation patterns mean that the species mix in the future will be different than that which has ever existed in the past within the area.) In this case the reference condition should

[5] See Angelsen and Kaimowitz (1999) and Chomiz *et al*. (2006) for comprehensive analysis of deforestation agents and drivers as an example.

be the condition which existed prior to the commencement of significantly degrading activities in the area, even if this condition is unlikely to be achieved in the future.

Note that in some cases the reference condition may be the present condition. For instance, where degradation of an ecosystem has not yet occurred, but is forecast to occur in the future, the reference condition is the current condition.

Step 8b: Identification of agents of change

Identify the main agent groups of change in the variable *X* (e.g.farmers, ranchers, loggers, planners or recreational users) and their relative importance (i.e. the amount of historical change in the variable *X* that can be attributed to each of them).

For location specific variables, the agents identified must include those identified as responsible for the change of the condition of the area from the reference condition to the current condition, but may also include other agents, including those who may be tending to drive the land back toward the reference condition.

For process specific variables, the agents identified must include those responsible for undertaking or maintaining the processes.

Agents identified should have relatively direct influence on the changes in the variable. Thus for instance a farmer on the land, or a zoning committee establishing land use guidelines, or an upwind industrial plant releasing emissions causing acid rain to fall on the area could be an agent, but a consumer buying meat produced on the land would probably not be. For this reason, it is possible that for some variables there will be no agents. For instance, if the variable in question is precipitation, which may vary as global warming occurs, the people responsible for global warming (all of us, more or less!) would not be agents.

Agents identified should have actual influence over changes in the variable. Thus for instance if a zoning committee establishes guidelines for land use, but they are almost never followed, the zoning committee is not be an agent.

To do this identification, use existing studies, historical records, maps, expert-consultations, field-surveys and other verifiable sources of information, as needed.

Determine the relative importance of each agent identified. Rate importance only in terms of the amount of direct influence that they have over events within the project area which will cause or inhibit changes in the variable.

If the relative importance of different agents is spatially correlated (e.g. small farmers are concentrated in the hills, while ranchers are on the plains), it may be useful to stratify the area accordingly, in order to recognize the different effects on the variable of the different agents.

For each identified agent group, provide the following information:

a) Name of the main agent group or agent.

b) Description of what the agent does to cause or inhibit change in the value of the variable *X.*

c) Brief description of the main social, economic, cultural and other relevant features of each main agent group. Limit the description to aspects that are relevant to understand why the agent group is deforesting.

d) Brief assessment of the most likely development of the population size or influence of the identified main agent groups.

e) Statistics on historical change in the variable attributable to each main agent group in the area.

Step 8c: Identification of drivers of change in the variable

For each identified agent group, analyze factors that drive their decisions. The goal is to identify the immediate causes of change in the variable, both historically and currently. Where no agents were identified in Step 8b, go to Step 8d.

Two sets of driver variables have to be distinguished:

a) Drivers explaining the quantity of change in the variable, such as:

- Prices of agricultural products,
- Costs of agricultural inputs,
- Population density, or
- Rural wages.

b) For location specific variables, identify the drivers explaining the location of change, also called "predisposing factors" (de Jong, 2007[6]), such as:

- Accessibility (such as vicinity to existing roads, railroads, navigable rivers and coastal lines),
- Slope,
- Proximity to markets,
- Proximity to existing or industrial facilities (e.g. sawmills, pulp and paper mills or agricultural products processing facilities),
- Proximity to water,
- Proximity to existing settlements,
- Land title history,
- Differences in soil depth, fertility, precipitation, or
- Management category of the land (e.g. National Park or indigenous reserve).

For each of these two sets of variables:

1) List key drivers and provide any relevant source of information that provides evidence that the identified drivers influence change in the variable.
2) Briefly describe for each main agent group identified how the key drivers have and will most likely impact on each agent group's decisions and actions.
3) For each identified key driver provide information about its likely future development, by providing any relevant source of information.

[6] De Jong, B.H.J.; Bazan, E. Esquivel; Quechulpa Montalvo, S. Application Of The Climafor Baseline To Determine Leakage: The Case Of Scolel Te. Lawrence Berkeley National Laboratory, 2007.

4) For each identified driver briefly describe the project measures that will be implemented to address them, if applicable.

5) Rank the identified drivers in terms of the degree of influence that they have had and are expected to have on change in the variable.

Step 8d: Identification of underlying causes of change in the variable *X*

The agents' characteristics and decisions, or the changes in the variables themselves, where no agents are identified, are themselves determined by broader forces, the underlying causes of change, such as:

- Land-use policies and their enforcement,
- Population pressure,
- Poverty and wealth,
- War and other types of conflicts,
- Property regime, or
- Spread of invasive species.

Document these causes using the following steps:

1) List the key underlying causes and cite any relevant source of information that provides evidence that the identified factors are an underlying cause for change in the variable.

2) Briefly describe how each key underlying cause determines or influences the key drivers identified in Step 8c and the decisions of the main agent groups identified in Step 8b, if agents and drivers have been identified.

3) For each identified key underlying cause provide information about its likely future development, by citing any relevant source of information.

4) For each identified underlying cause describe the project measures that will be implemented to address them, if applicable.

5) Rank the identified causes in terms of their historic and expected future impact on change of the variable.

Step 8e: Analysis of chain of events leading to change in the variable *X*

Analyze the relations between main agent groups, key drivers and underlying causes and explain the sequence of events that typically leads to or inhibits change in the variable. Determine the relative ranking of importance of the agents, drivers and causes. Consult local experts, literature and other sources of information, as necessary. Briefly summarize the results of this analysis in the project description. At the end, provide a concluding statement from the above analysis (Steps 3.1-3.4) about the most likely future evolution of the variable *X* in the area.

Step 8f: Conclusion

Step 8 must conclude with a statement about whether the available evidence about the most likely future trend in change in the variable *X* within the area is:

- Inconclusive; or

- Conclusive. In order to be conclusive, the analysis of chain of events undertaken in Step 8e must show that at minimum 80% of the identified drivers, agents and causes are tending to drive the future trend in change in the variable *X* in the same direction, and that the relative ranking points to these drivers agents and causes as being the key drivers of change.

In the case where the evidence is conclusive, state whether the weight of the available evidence is sufficient to allow quantitative estimation of the future value of the variable, and if so, why.

Step 9: Reassess the category of variable being projected

Goal: Based on the work undertaken in the previous steps, reassess whether the previous determination of the category of the variable, undertaken in Step 3, remains correct, or whether information gathered in subsequent steps makes it likely that the variable should fall into a different category than that originally determined. Document the steps and data used to make this determination.

Methods and guidance: The category of the variable being examined was determined on a preliminary basis in Step 3. However, work undertaken in Step 8 may cause a reassessment of the category of the variable. As well, many variables fall into more than one category, based on the types of drivers, agents and causes influencing that variable. For each identified driver, agent or cause, note the expected degree of influence on the value of the variable *X* that it has, as determined in Step 8.

The category of the variable is determined by identifying the degree of importance of the agents, drivers and causes falling to each of the three categories – controlled, planned and systemic, using the flowing decision key, as follows:

- If substantial control (control of more than 75% of the change in the variable) in the future under the scenario being examined is exerted by the project proponent or by agents under his or her control, then the variable is controlled. If not, then:
- If substantial control (control of more than 75% of the change in the variable) in the future under the scenario being examined is exerted by one or more known agents who act independently of the project proponent, and who have the direct ability to cause or influence the change in the variable, the variable is planned. If not, then
- The variable is systemic.

Step 10 Analysis of constraints to future values of the variable *X*

Goal: Determine what physical, social, economic or other constraints exist which limit the possible values of the variable. Document the data and methods used to make these determinations.

Methods and guidance: Projection of future values for the variable must recognize any limits which exist to the upper or lower plausible values of the variable. These constraints can be caused by physical, biological, logistical, economic or other limitations. For example:

1) <u>Land use constraints</u>: If changes in the variable result in whole or part from human activities or management, there may be biophysical and infrastructure constraints (soil, climate, elevation, slope, distance to roads, supply of an input etc.) that limit the geographical area where the management or activity could plausibly take place. These constraints could act by creating absolute limits, or by creating limits perceived by the main agents of change.

2) Economic constraints: Even if there are no immediate biophysical constraints, there may be limits to resources which slow the pace of change, or some change could plausibly occur, but would in fact result in uneconomic activities, and therefore are unlikely to occur.

3) Physical constraints: There may be physical limits to the possible values which the variable can take.

4) Institutional constraints: An activity leading to change in the variable may be possible and economically viable, but forbidden by laws which are enforced, or by custom, or may be made unlikely by limits in institutional capacity.

Limits may be of two sorts:

- Absolute. Absolute limits are points beyond which the variable cannot go (for instance, soil carbon levels less than zero), or is quite unlikely to go (for instance, tree biomass accumulations above the limits set by the ecosystem and the species mix). Note that limits to variables such as tree biomass may not be absolute – for instance, an ecosystem could at times exceed the normal maximum value – but can be treated as such for the purposes of projecting values of the variable, since exceeding these limits is relatively unlikely.
- Break points. Break point limits are limits at which the rate of change of the variable will change. For instance:
  - A situation in which change in a variable beyond a certain value requires a different biological process with different process rates than that occurring before the breakpoint was reached.
  - There exists a point at which all of the good agricultural land will have been deforested, after which different agents will undertake deforestation of marginal land for a different use and at a different rate.

The project proponent must research and document the likely constraints to the plausible values of the variable. These may be very simple (for instance, the project cannot burn less than no fuel) or they may be very complex (for instance limits to deforestation within a broad landscape with many land use processes under way). Some variables may also be effectively unlimited in their upper, lower, or both values. Note also that some variables may have both absolute limits and break points prior to reaching the absolute limit.

Step 11: Projection of controlled variables

Goal: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the controlled variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

Methods and guidance: Controlled variables will generally be projected as part of the completion of the ex-ante project scenario projection (Task 3 in module *VM0021 Soil Carbon Quantification Methodology*). In this case, projection of the variable will reflect the project's planned actions and results. Project proponents should make these projections based on a project plan which considers feasibility, costs, and potential performance risks. Projected values of the variable must reflect these considerations.

In rare circumstances, controlled variables may occur in projections made as part of Task 2 in *VM0021 Soil Carbon Quantification Methodology*, the ex-ante baseline. In these cases, project proponents must independently verify that the projected values of the variables are consistent with those which would be expected were the variable systemic or planned, rather than controlled. Project proponents are therefore required to complete the work laid out in Steps 5, 6 or 7 as appropriate, 8 and 9, and 12 or 13 as appropriate, and must demonstrate that the projected values of the variable are no less conservative than those which would be projected if the variable were systemic.

Step 12: Projection of planned variables

Goal: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the planned variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

Methods and Guidance: Planned variables occur when specific agents not under the control of the proponent have stated plans for the value of the variable. These stated plans may be used as the projected values providing the following conditions are met:

a) The stated plans are feasible given the agent's abilities and resources.
b) The stated plans are consistent with local, regional, or sectoral practice and history. In order to demonstrate this, the project proponent may need to undertake some or all of the work outlined in Steps 5 through 9 of this module.
c) The stated plans were made prior to the commencement of the design of the carbon project. If this is not the case, the project proponent must demonstrate that the plans were made independent of, and ideally without knowledge of, the carbon project.
d) The agent making the plans does not stand to gain directly from the carbon project, and it can be demonstrated that the plans were not made in the expectation of such a gain.

If these conditions cannot be met, project proponents are required to demonstrate that the projected values of the variable based on the agent's plans are no less conservative than those which would be projected if the variable were systemic, and must therefore complete the work laid out in Steps 5, 6 or 7 as appropriate, 8 and 9, and 12 or 13 as appropriate.

Step 13: Projection of process specific systemic variables

Goal: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the process specific variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

Methods and guidance: Projection of process specific systemic variables must be undertaken using one of three techniques for projecting the future values of the variable.

- Linear extrapolation: Projection of the existing trajectory of change in the value of the variable into the future. In general, this is the simplest approach. This approach is applicable where the project proponent believes that the drivers, agents and causes leading to change in the variable within the stratum are likely to remain relatively unchanged in the future.
- Modified trajectory: Projection of the future values of the variable based on the existing trajectory, modified to reflect the expected impacts of changes in one or two relatively independent drivers, agents or causes. This technique is much less complex than the modeled technique, while still integrating the effects of expected changes in the factors influencing the variable.
- Modeled: Projection of future values of the variable based on a function or model which integrates the impacts of multiple drivers, agents and causes on the variable. This technique is typically highly data intensive, since the project proponent must have enough data on past changes in the variable and changes in drivers, agents and causes to determine the causal relationships within the system. When this technique is used, the data on past values of the variable is used to develop and truth the model. This technique may be particularly suitable where existing models have been developed and peer reviewed in the scientific literature for forecasting changes in the variable. Currently, models such as Geomod are useful for modeling of this sort, but project proponents should use the best available models currently available at the time of the project.

Based on the data generated on the variable, the processes influencing its value, and the degree to which knowledge of the processes leading to change in the variable exists, choose the most suitable technique, and document the reasons for the choice.

Step 13b: Linear extrapolation

The linear extrapolation method is used where the project proponent has evidence to support the supposition that the existing trend line of change in the variable will continue into the future. Thus for instance if non-tree woody biomass has been increasing steadily at a rate of 0.01 t /ha/yr throughout the historic period examined, the project proponent may propose that this will continue into the future. The linear extrapolation may be based on a straight line, as in the example given, or may be based on a curve extracted from the historic information. The steps in the linear extrapolation method are:

Step 13b.1: Project existing curve

Based on the curve extrapolated from the historic data, project values for the variable *X* in the stratum for each future time point analyzed within the project crediting period.

Step 13b.2: Check for conservatism

Based on the analysis of agents, drivers and causes, the project proponent must determine and document whether there are any reasonably possible changes in the status of these factors which might cause the use of the trajectory to be non-conservative. If any such factors are noted, the project proponent must use the modified trajectory method given in Step 13c, or the modeled method given in Step 13d, rather than the linear extrapolation method.

Step 13b.3: Check for limits of possible values of the variable

Based on the work undertaken in Step 9, check whether the values for X based on the linear extrapolation reach a limit of the possible values of the variable. If no limit is reached, use the values derived from the historic curve as the projected values of the variable.

If an absolute limit is reached, all values of the variable above an upper limit or below a lower limit must default to the limit value, and the revised values are the projected values.

If a break point is reached, the project proponent must adjust the future curve from that point onwards to reflect the altered dynamics of the variable beyond the breakpoint, and repeat Steps 1 through 3 for this new curve.

Step 13c: Modified trajectory

The modified trajectory technique uses the same steps and methods as those given in section 13b for the linear extrapolation technique above, except that the following steps are undertaken prior to undertaking Step 13b.1:

Step 13c.1: Identify modifiers

Identify the key drivers, agents or causes which are expected to modify the trajectory.

Step 13c.2: Assess conditions of effect

Assess the conditions under which each identified driver, agent or causes is expected to modify the trajectory.

Step 13c.3: Document expected future values

Document the expected future values of the drivers, agents or causes. Demonstrate that these projected values are supported by assessments by independent agencies or parties, or that they are derived from documented assessments of related drivers or causes. Demonstrate that the projected future values of the drivers and causes are conservative projections.

Step 13c.4: Modify the trajectory

Modify the trajectory of the variable based on those projected future values of the drivers, agents or variables which are well backed by independent projections, interpreted conservatively.

Step 13d: Modeled

Step 13d.1: Current conditions

Document the current condition of all significant agents and drivers. The modeled approach depends on clear knowledge of the conditions and trends in the agents and drivers influencing the variable. The project proponent must document the current conditions of these drivers and variables. Any information on the past status of the drivers and variables, derived from studies, oral history, government statistics, the remote sensing analysis undertaken in Step 7, and other sources used to determine past status must be documented.

Step 13d.2: Correlation

Determine correlation between values of the variable and identified agents and drivers. Quantitative relationships must now be derived between the drivers and agents and the values of the variable. Typically this will involve some form of multi-factorial analysis. This step should rely to some degree on existing studies of the drivers of change in the variable, but must also include an analysis of these relationships based on the historic documentation of change in the value of the variable, determined in Steps 6 and 7, and the historic trends in the drivers, determined in Step 8.

Step 13d.3: Modeling

Model expected current conditions based on these correlations. Based on the current conditions of the agents and drivers, and the proposed model, a projection of current conditions from the model must be undertaken to determine how well it correlates with the actual current values of the variable.

Step 13d.4: Review

Identify discrepancies, look for possible causes, finalize model. If tests of the model or models show significant discrepancies from actual conditions, or appear to forecast conditions which are highly improbable in the future, the models must be re-examined, and corrections made. The assumptions behind all elements of the model, and the reasons for all changes made to it, must be documented.

Step 13d.5: Project

Conservatively determine expected future values of drivers and agents used as model inputs for the first monitoring period, and project values of the variable for that time. Determine the future values of drivers and agents for the first monitoring period. The reasons for the projections of these values, and a justification of the conservativeness of these projections, must be documented. Based on these projected values, determine the value or values of the variable at the time of the first future verification period.

Step 13d.6: Create a time series

Repeat Step 13d.5 for each future monitoring period. The result will be a series of values covering at least the entire project crediting period.

Step 14: Projection of location specific systemic variables

Goal: Based on the work undertaken in the previous steps, prepare a projection of the most probable future value of the location specific systemic variable over the required time period. Results must consist of a time series of values, with not more than 5 years between each projected value. Document the methods and data used to make this projection. Document the risk and degree of impact of any possible uncertainties or variations in actions or conditions, and the resulting range of uncertainty in the value of the variable at each time point.

Methods and guidance: The objective of this step is to project, for each future time period of interest, the estimated value of the variable *X* across the area.

Depending on the nature of the variable, projections must be made either:

- Using a stratified approach, where the values of the variable at any given point in time will be projected to be the same for all locations within the stratum area.
- Using a location specific approach, where variation in the value of the variable across the area will be quantified down to some minimum polygon size or pixel resolution. In this case the analysis may still be undertaken on a stratum by stratum basis, but the projected values of the variable will vary within a given stratum.

In general, it is strongly recommended within this methodology, to use a stratified approach. In many cases the amount of data, knowledge of systemic processes and patterns, and the sophistication of the modeling required to achieve projection using the location specific approach will exceed what can reasonably be provided. However, variables may exist for which meaningful stratification is difficult to achieve, and for which modeling capacity may make the location specific approach suitable.

The outputs for the two approaches will therefore be:

- For the stratified approach, a map of the projected stratification for the variable for each time period analyzed, and a value for the variable for each stratum for each time period analyzed. Because in many cases the values of the drivers for the variable may change from time period to time period, the stratification can also change through time. Thus for example if the variable in question is the percentage of area deforested, the strata will be established based on differences in the deforestation rate, and each stratum will have an associated total area deforested, associated percentage area deforested, and annual percentage deforestation rate. If population is one of the drivers of deforestation, and if future changes in the location of population in the area are forecast, stratification may also change over time.
- For the location specific approach, a map of the locations at which specific values of the variable are projected to exist, shown either as pixels or as polygons. And an associated value for the variable for each pixel or polygon.

Step 14a: Determine the approach to be used

The project proponent must choose whether to use the stratified approach or the location specific approach. As discussed above, the stratified approach is recommended in most cases.

The exception to this guidance may occur if the project proponent believes that the location (as versus the quantity) of changes in the value of the variable is highly correlated with a single driver. For instance, if deforestation is highly correlated with land quality, the project proponent may be able to extrapolate the likely locations of deforestation by projecting that the best land will be deforested first.

Step 14b Determine proposed projection technique

Three techniques for projecting the future values of the variable may be used:

- Linear extrapolation: Projection of the existing trajectory of change in the value of the variable into the future. In general, this is the simplest approach. This approach is applicable where the project proponent believes that the drivers, agents and causes leading to change in the variable within the stratum are likely to remain relatively unchanged in the future.
- Modified trajectory: Projection of the future values of the variable based on the existing trajectory, modified to reflect the expected impacts of changes in one or two relatively independent drivers, agents or causes. This technique is much less complex than the modeled technique, while still integrating the effects of expected changes in the factors influencing the variable.
- Modeled: Projection of future values of the variable based on a function or model which integrates the impacts of multiple drivers, agents and causes on the variable. This technique is typically highly data intensive, since the project proponent must have enough data on past changes in the variable and changes in drivers, agents and causes to determine the causal relationships within the system. When this technique is used, the data on past values of the variable is used to develop and truth the model. This technique may be particularly suitable where existing models have been developed and peer reviewed in the scientific literature for forecasting changes in the variable.

Based on the data generated on the variable, the processes influencing its value, and the degree to which knowledge of the processes leading to change in the variable exists, choose the most suitable technique, and document the reasons for the choice.

Step 14c: Check stratification

At this point review the proposed stratification of the area. Based on the data gathered to this point, the choices of approach and technique must be undertaken, based on the following guidance:

- If either the linear extrapolation technique or the modified trajectory technique has been chosen, ensure that the stratification recognizes any changes in drivers, agents or causes across the area that are likely to result in significant changes in the value of the variable. It is highly recommended that if these techniques are used, a stratified approach should also be used, making it important to ensure that the strata reflect the significant drivers, agents and causes.
- If the modeled technique has been chosen, and the location specific approach will be used, project proponents may consider reducing the number of strata to reflect the fact that the model will account for many of the changes in drivers, agents and causes across the area, and the locations of change will be determined at a substratum level. It is possible that if the modeled technique and location specific approach are used, the entire area of interest can be considered a single stratum, unless the differences in processes across the area require the preparation of more than one model.

Step 14d: Linear extrapolation

The linear extrapolation method is used where the project proponent has evidence to support the supposition that the existing trend line of change in the variable will continue into the future. Thus for instance if non-tree woody biomass has been increasing steadily at a rate of 0.01 t /ha/yr throughout the historic period examined, the project proponent may propose that this will continue into the future. The linear extrapolation may be based on a straight line, as in the example given, or may be based on a curve extracted from the historic information. The steps in the linear extrapolation method are:

Step 14d.1: Project existing curve

Based on the curve extrapolated from the historic data, project values for the variable *X* in the stratum for each future time point analyzed within the project crediting period.

Step 14d.2: Check for conservatism

Based on the analysis of agents, drivers and causes, the project proponent must determine and document whether there are any reasonably possible changes in the status of these factors which might cause the use of the trajectory to be non-conservative. If any such factors are noted, the project proponent must use the modified trajectory method given in Step 14e, or the modeled method given in Step 14f, rather than the linear extrapolation method.

Step 14d.3: Check for limits of possible values of the variable

Based on the work undertaken in Step 9, check whether the values for X based on the linear extrapolation reaches the limit of the possible values of X. If no limit is reached, use the values derived from the historic curve as the projected values of the variable.

If an absolute limit is reached, all values of the variable above an upper limit or below a lower limit must default to the limit value, and the revised values are the projected values.

If a break point is reached, the project proponent must adjust the future curve from that point onwards to reflect the altered dynamics of the variable beyond the breakpoint, and repeat Steps 1 through 3 for this new curve.

If the values of the variable are being determined using a stratified approach, no further work is required. Since linear extrapolation does not depend on modeling which would allow the calculation of specific values for a specific point, the location specific approach should not be used. The one exception might be in the case of a variable of only two possible values (for instance, deforested or not deforested), with location specific breakpoints such as good soil quality versus marginal soil quality. Even in these cases, it is recommended that the projections be undertaken on a stratified basis, with the stratification adjusted to recognize the location specific breakpoints. If however, the project proponent believes that use of a location specific approach is required, they must undertake the work described in Step14f to develop the modeling tools to allow location of the changes in the values of the variable within the stratum.

Step 14e: Modified trajectory

The modified trajectory technique uses the same steps and methods as those given in Step 14d for the linear extrapolation technique above, except that the following steps are undertaken prior to undertaking Step 14d.1.

Step 14e.1: Key modifiers

Identify the key drivers, agents or causes which are expected to modify the trajectory.

Step 14e.2: Modifying conditions

Assess the conditions under which each identified driver, agent or causes is expected to modify the trajectory.

Step 14e.3: Expected future values

Document the expected future values of the drivers, agents or causes. Demonstrate that these projected values are supported by assessments by independent agencies or parties, or that they are derived from documented assessments of related drivers or causes. Demonstrate that the projected future values of the drivers and causes are conservative projections.

Step 14e.4: Modify

Modify the trajectory of the variable based on those projected future values of the drivers, agents or variables which are well backed by independent projections, interpreted conservatively.

Step 14f: Modeled

Step 14f.1: Current conditions

Map or document the current condition of all significant agents and drivers. The modeled approach depends on clear knowledge of the conditions and trends in the agents and drivers influencing the variable. The project proponent must document the current conditions of these drivers and variables. Any information on the past status of the drivers and variables, derived from studies, oral history, government statistics, the remote sensing analysis undertaken in Step 7, and other sources must also be documented.

Step 14f.2: Correlate

Determine correlation between values of the variable and identified agents and drivers. Quantitative relationships must now be derived between the drivers and agents and the values of the variable. Typically this will involve some form of multi-factorial analysis. This step may rely to some degree on existing studies of the drivers of change in the variable, but must also include an analysis of these relationships based on the historic documentation of change in the value of the variable, determined in Steps 6 and 7, and the historic trends in the drivers, determined in Step 8.

Step 14f.3: Check model against current conditions

Model expected current conditions based on these correlations. Based on the current conditions of the agents and drivers, and the proposed model, a projection of current conditions from the model must be undertaken to determine how well it correlates with the actual current values of the variable. Note that the model derived and developed in Step 14f.2 and this step may be unique for each stratum, or may be the same across all strata, in which case the differences in the strata will arise solely from differences in the values of one or more agents or drivers between the strata.

Step 14f.4: Review and revise model

Identify discrepancies, look for possible causes, finalize model if tests of the model or models show significant discrepancies from actual conditions, or appear to forecast conditions which are highly improbable in the future, the models must be re-examined, and corrections made. The assumptions behind all elements of the model, and the reasons for all changes made to it, must be documented.

Step 14f.5: Model future values

Conservatively determine expected future values of drivers and agents used as model inputs for the first monitoring period, and project values of the variable for that time. Determine the future values of drivers and agents for the first monitoring period. The reasons for the projections of these values, and a justification of the conservativeness of these projections, must be documented. Based on these projected values, determine the value or values of the variable at the time of the first future verification period.

Step 14f.6: Project stratification changes

For variables which are being projected on a stratified basis, project the location of any changes in the stratification which may result from the modeling or from projected changes in drivers or agents.

Step 14f.7: Project location specific values

For variables which are being projected on a located basis, project the value of the variable for each point or polygon. These projections can be accomplished using programs such as Geomod, or custom programs or approaches.

Step 14f.8: Model a time sequence

Repeat Step 14f.5, 14f.6, and, if used, 14f.7 for each future monitoring period. The result will be a series of values covering at least the entire project crediting period.

6 PARAMETERS

Data Unit / Parameter:	*X*
Data unit:	Varies
Description:	The variable for which a projection of future values is being made
Source of data:	Future values determined using the methods given in the module
Justification of choice of data or description of measurement methods and procedures applied:	N/A
Any comment:	

7 REFERENCES AND OTHER INFORMATION

GOFC-GOLD, 2009, Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting, GOFC-GOLD Report version COP14-2,49 (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada)

De Jong, B.H.J.; Bazan, E. Esquivel; Quechulpa Montalvo, S. (2007) Application Of "The Climafor Baseline" To Determine Leakage: The Case Of Scolel Te. Lawrence Berkeley National Laboratory http://escholarship.org/uc/item/3f68q2wh;jsessionid=5EC491008DE4BE3DAC334979C0DB9370#page-1 (last visited 16-09-2011)

Angelsen and Kaimowitz (1999) Rethinking the Causes of Deforestation: Lessons from Economic Models, World Bank Res Obs 14 (1): 73-98.

Chomitz, K. M., G. A. B. Da Fonseca, K. Alger, D. M. Stoms, M. Honzák, E. Charlotte Landau, T. S. Thomas, W. Wayt Thomas, and F. Davis. 2006. Viable reserve networks arise from individual landholder responses to conservation incentives. Ecology and Society 11(2): 40. (Last visited: 19-09-2011 URL: http://www.ecologyandsociety.org/vol11/iss2/art40/)

VCS methodology *VM0015 Methodology for Avoided Unplanned Deforestation*

DOCUMENT HISTORY

Version	Date	Comment
v1.0	16 Nov 2012	Initial version released