PLAN VIVO

PV Climate Tool

# PT#NWB

# Estimation of Change in Non-woody Biomass in Grasslands

*Version 1.0*

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**Developed by:**

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# Contents



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# 1 Summary

This tool is part of the PV Climate *Agriculture and Forestry Carbon Benefit Assessment Methodology* (**PM001**), and is applied within Module **PU001** *Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects*. It provides procedures for estimating changes in non-woody biomass carbon stocks in PV Climate project areas in grassland and wooded grassland under baseline and project scenarios. Procedures include using stratified random sampling with values for non-woody belowground biomass obtained from direct measurement or through time-bound measurements of above-ground non-woody biomass as a proxy for belowground non-woody biomass, to determine values for the following parameters that are used to estimate baseline and project removals in non-woody biomass following **PU001**:

$C_{BGNWB_{BSL,t2,i}}$ Average carbon stock in belowground non-woody biomass in the control plots for baseline scenario stratum *i* in year *t2* (t $CO_2$e/ha)

$C_{BGNWB_{BSL,t1,i}}$ Average carbon stock in belowground non-woody biomass n in the control plots for baseline scenario stratum *i* in year *t1* (t $CO_2$e/ha)

$\Delta C_{AGNWB\_PROJ,t}$ Change in carbon stock in aboveground non-woody biomass under the project scenario within the project area in year *t* (t $CO_2$e)

$\Delta C_{BGNWB\_PROJ,t}$ Change in carbon stock in belowground non-woody biomass under the project scenario within the project area in year *t* (t $CO_2$e)

The tool is applicable globally to project areas in grassland and wooded grassland; and project interventions that affect non-woody biomass, either positively or negatively.

# 2 Sources

Procedures applied in the tool are derived from the following sources:

**AR-TOOL14** Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities, Version 4.2

This tool applies the following Plan Vivo methodology elements:

**PT003** Guidance for the Use of Models Validated with Measurements in PV Climate Projects, Version 1.0

**PU005** Estimation of uncertainty of carbon benefit estimates in Plan Vivo projects. Version 1.1.

# 3 Definitions

The tool follows all definitions in the latest versions of the PV Climate Glossary, **PM001** and **PU001**, and the following:

**Grassland-** an area in which the vegetation is dominated by a nearly continuous cover of grasses, with little or no tree and shrub cover[1].

**Wooded grassland-** an area with 10-40% tree and shrub cover[1].

**Natural grassland-** Natural grassland indicates that the vegetation is developed under a minimum human interferences (not mowed, drained, irrigated, sown, fertilised or stimulated by chemicals which may influence production of biomass)[2].

# 4 Applicability Conditions

The tool is applicable globally to project areas and project interventions that meet applicability conditions of **PM001** and **PU001**, and the following conditions:

a) Land cover in the project area is *grassland* or *wooded grassland* in either the baseline or project scenario. This includes, project interventions that involve a change between two types of land cover (one of which is either *grassland* or *wooded grassland*), for example grassland to shrubland; as well as interventions where grassland remains grassland.

b) The project intervention does not involve a conversion from *natural grassland* to another land cover type.

# 5 Procedures

## 5.1 Aboveground non-woody biomass

Aboveground non-woody biomass in *grassland* or *wooded grassland* can have significant temporal variability, and high risk of non-permanence. The Intergovernmental Panel on Climate Change

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[1] FAO (2005) Grasslands of the World. Plant Production and Protection Series No. 34. https://www.fao.org/4/y8344e/y8344e05.htm

[2] EEA (2019) Updated CLC illustrated nomenclature guidelines. https://land.copernicus.eu/content/corine-land-cover-nomenclature-guidelines/html/index-clc-321.html

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(IPCC, 2003) states "*carbon stocks in the aboveground herbaceous component [of grasslands] are usually small and relatively insensitive to management; thus aboveground grass biomass is only considered for estimating non-$CO_2$ emissions from burning*".

In *grassland* or *wooded grassland*, the change in above-ground non-woody biomass in the baseline and project scenario can be assumed to be zero throughout the crediting period; and $\Delta C_{AGNWB\_BSL,t}$ and $\Delta C_{AGNWB\_PROJ,t}$ can be set to zero for all values of $t$.

Aboveground non-woody biomass can act as a useful proxy for belowground non-woody biomass, which can be a significant carbon pool in *grassland* or *wooded grassland*. Temporal variability in aboveground non-woody biomass must be taken into account, however. Procedures to account for changes in belowground non-woody biomass in *grassland* or *wooded grassland*, including using aboveground non-woody biomass as a proxy, are described in Section 5.2 below.

## 5.2 Belowground Non-woody Biomass

### 5.2.1 Estimating Belowground Non-Woody Biomass Carbon Stock at a Point in Time

#### 5.2.1.1 Stratified Random Sampling

If non-woody biomass distribution over the project area(s) is not homogeneous, stratification should be applied to improve the precision of biomass estimation. Different stratifications may be appropriate for the baseline and project scenarios to achieve optimal precision of estimation of net GHG removals[3]. In particular:

a) For baseline net GHG removals, stratification of the area should be considered according to major vegetation types and cover and/or land use types, as well as soil type and rainfall patterns;
b) For actual net GHG removals the stratification for estimations should consider the project interventions and the stratification for measurements should be based on the actual implementation of the project interventions, as well as the vegetation types and cover/and or land use types. If natural or anthropogenic impacts (e.g. local fires) or other

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[3] At a landscape scale, the World Terrestrial Ecosystems approach (which stratifies based on climate region, landforms and land cover) for standardised terrestrial ecosystems could be used to support the stratification across a landscape or catchment (Sayre et al., 2020).

factors (e.g. soil type or rainfall) significantly alter the pattern of biomass distribution in the project area, then the stratification should reflect this.

Under this method, sample plots should be installed at stratified, randomly selected locations within each stratum (Appendix 1).

#### 5.2.1.2 Methods of Belowground Non-woody Biomass Estimation

##### 5.2.1.2.1 Physical Sampling

Measurements of belowground non-woody biomass can be made using one of the following approaches (further guidance on the listed methods can be found in Appendix 1):

- Core sampling
- Pit sampling
- Ingrowth core method
- Destructive, specific plant sampling

Frequency of sampling should take in to account any likely temporal variability (e.g. due to seasonality).

If measuring below-ground non-woody biomass, projects should review the data sharing request in Appendix 2.

##### 5.2.1.2.2 Aboveground and Belowground Non-Woody Biomass Model

Projects wishing to develop models for estimating the non-woody belowground biomass from non-woody aboveground biomass may do so but must:

- develop the model using above and belowground non woody biomass data collected from the project area specifically at the time of baseline/monitoring event, for the different strata determined in Section 5.2.2.1, following the procedures in **PT003**.
- use aboveground non-woody biomass data in the model development collected using random stratified sampling and based on the approaches in Appendix 1
- regression analysis must be presented that shows the measured vs modelled non woody belowground biomass results.

Aboveground biomass measurements can be collected across any control and/or project area(s) using stratified random sampling with the belowground non-woody biomass determined from the derived model, to determine the belowground non-woody biomass carbon pool.

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Model development must be repeated at each monitoring period (i.e. a new model developed), to ensure the model is relevant for the different seasonal and management conditions (e.g. dry vs wet season or management impacts such as grazing or fire that will likely result in changes in aboveground biomass but not necessarily reflect the same change in below ground biomass).

### 5.2.2 Calculating Carbon Stocks and Stock Changes

Carbon stocks in sample plots are calculated with Equation 1.

$$C_{BGNWB,i,p,t} = \frac{44}{12} \times CF_{BGNWB,i,p,t} \times \frac{B_{BGNWB,i,p,t}}{A_p}$$

*Equation 1*

Where:

$C_{BGNWB,i,p,t}$ Carbon stock in belowground non-woody biomass in sample plot $p$, in stratum $i$, at time $t$ ($tCO_2e$/ha)

$CF_{BGNWB,i,p,t}$ Carbon fraction of belowground non-woody biomass in sample plot $p$, in stratum $i$, at time $t$ (t C /t d.m; a default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value)

$B_{BGNWB,i,p,t}$ Belowground non-woody biomass in non-woody biomass in sample plot $p$, in stratum $i$, at time $t$ (t d.m.; see Section 5.2.1.2)

$A_p$ Extent of the sample plot (ha)

$\frac{44}{12}$ Molar mass of $CO_2$ used to convert t C to $tCO_2e$ (unitless)

#### 5.2.2.1 Calculation of Average Belowground Non-woody Biomass Carbon Stock in Control Areas

When sample plots are used to estimate belowground non-woody carbon stocks in control areas, the average carbon stock in each baseline scenario stratum at a point in time is calculated with Equation 2.

$$C_{BGNWB_{BSL,t,i}} = \frac{\sum_{p=1}^{n} C_{BGNWB,i,p,t}}{n}$$

*Equation 2*

Where:

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$C_{BGNWB_{BSL,t,i}}$ Average carbon stock in belowground non-woody biomass in the control plots for baseline scenario stratum *i* in year *t*

$C_{BGNWB,i,p,t}$ Carbon stock in belowground non-woody biomass in sample plot *p*, in stratum *i*, at time *t* ($tCO_2e$/ha; see Equation 1)

$n$ Number of sample plots

#### 5.2.2.2 Calculation of Change in Belowground Non-woody Biomass Carbon Stock in Project Areas

When sample plots are used to estimate change in belowground non-woody biomass carbon stocks in the project areas, change in carbon stock is calculated with Equation 3 and Equation 4.

$$\Delta C_{BGNWB\_PROJ,t} = \frac{C_{BGNWB_{PROJ,t2,i}} - C_{BGNWB_{PROJ,t1,i}}}{T}$$

*Equation 3*

Where:

$\Delta C_{BGNWB\_PROJ,t}$ Change in carbon stock in belowground non-woody biomass under the project scenario within the project area in year *t* (t $CO_2e$)

$C_{BGNWB_{PROJ,t2,i}}$ Carbon stock in belowground non-woody biomass in the project area in year *t2* (t $CO_2e$; see Equation 4)

$C_{BGNWB_{PROJ,t2,i}}$ Carbon stock in belowground non-woody biomass in the project area in year *t1* (t $CO_2e$; see Equation 4)

$T$ Time between *t1* and *t2* (years)

$$C_{BGNWB_{PROJ,t,i}} = \sum_{i=1}^{x} \frac{\sum_{p=1}^{n} C_{BGNWB,i,p,t}}{n} \times A_i$$

*Equation 4*

Where:

$C_{BGNWB_{PROJ,t,i}}$ Carbon stock in belowground non-woody biomass in the project area in year *t* (t $CO_2e$)

$C_{BGNWB,i,p,t}$ Carbon stock in belowground non-woody biomass in sample plot *p*, in stratum *i*, at time *t* ($tCO_2e$/ha; see Equation 1)

$n$ Number of sample plots

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$A_i$ Extent of project area in stratum *i* (ha)

$x$ Number of strata

### 5.2.3 Uncertainty

Uncertainty calculations depend on the approach used to estimate the baseline and project scenario belowground non woody biomass and carbon stock changes:

- Where physical sampling is used, uncertainty must account for sampling error following the procedures in **PU005** Section 5.1.1. Measurement error is assumed to be zero provided QA/QC procedures in field and laboratory procedures are applied.
- Where above and belowground non-woody biomass modelling is used, uncertainty is the sum of both sampling error and model prediction error. Sampling error captures error from only a portion of the area being sampled and subsequently modelled. Model prediction error captures error and uncertainty in model parameters and overall model structure. The sum of sampling error and model prediction error is calculated with Equation 5.

$$U_x = \sqrt{U_{x,sample}{}^2 + U_{x,model}{}^2}$$

*Equation 5*

Where:

$U_x$ Combined sample and model uncertainty of carbon stock estimate *x* at a 90% confidence level (percent)

$U_x, sample$ Sample uncertainty of carbon stock estimate *x* at a 90% confidence level (percent; see **PU005** Section 5.1.1)

$U_{x,model}$ Model uncertainty of carbon stock estimate *x* at a 90% confidence level (percent; see **PT003** Equation 2)

To estimate the uncertainty associated with belowground non-woody biomass samples following the procedures in **PU005** requires calculation of the standard deviation of the estimated value ($SD_{CDx}$) and the carbon density for the estimated value ($CDx$).

For the estimated value of carbon stock in belowground non-woody biomass $CDx = C_{BGNWB}$, and the standard deviation of $C_{BGNWB}$ is calculated with Equation 4 and Equation 5.

# 6 Parameters

| | |
|---|---|
| **Data/Parameter** | $CF_{BGNWB,i,p,t}$ |
| **Units** | t C /t d.m |
| **Description** | Carbon fraction of belowground non-woody biomass in sample plot *p*, in stratum *i*, at time *t* |
| **Equations** | Equation 1 |
| **Source** | 2006 IPCC Guidelines for National GHG Inventories. Chapter 6 Grasslands, P 6.2.9 |
| **Value** | A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value |
| **Justification of choice of data or description of measurement methods and procedures applied** | Default carbon fraction for herbaceous biomass under the IPCC is 0.47 tonne d.m-1 p 6.29, Chapter 6 Grasslands, 2006 IPCC Guidelines for National GHG Inventories. |
| **Purpose of Data** | Estimation of carbon stock in belowground non-woody biomass in sample plots |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $B_{BGNWB,i,p,t}$ |
| **Units** | t d.m. |
| **Description** | Belowground non-woody biomass in non-woody biomass in sample plot *p*, in stratum *i*, at time *t* |
| **Equations** | Equation 1 |
| **Source** | Estimated from physical sampling or an above and belowground non-woody biomass model (see Section 5.2.1.2) |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Physical sampling and empirical models comparing aboveground and belowground non-woody biomass are established methods of estimating belowground non-woody biomass. |

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| | |
|---|---|
| **Purpose of Data** | Estimation of carbon stock in belowground non-woody biomass in sample plots |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $A_p$ |
| **Units** | ha |
| **Description** | Extent of the sample plot used to estimate belowground non-woody biomass |
| **Equations** | Equation 1 |
| **Source** | Measured for each sample plot |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Sample plot area can be derived from plot dimensions. |
| **Purpose of Data** | Estimation of carbon stock in belowground non-woody biomass in sample plots |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $n$ |
| **Units** | None |
| **Description** | Number of sample plots |
| **Equations** | Equation 2, Equation 4 |
| **Source** | Survey of sample plots |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Used when a survey of sample plots is carried out |
| **Purpose of Data** | Estimation of average carbon stock in belowground non-woody biomass in control plots and project area |

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|---|---|
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $T$ |
| **Units** | years |
| **Description** | Time between *t1* and *t2* |
| **Equations** | Equation 3 |
| **Source** | Calculated as time elapsed (in years) between *t1* and *t2*. Include fractions of years e.g. 4.2. |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | NA |
| **Purpose of Data** | Estimation of change in carbon stock in belowground non-woody biomass under the project scenario |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $A_i$ |
| **Units** | ha |
| **Description** | Extent of project area in stratum *i* |
| **Equations** | Equation 4 |
| **Source** | Boundary maps of project areas |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Calculated as the sum of the extent of all project areas within a given stratum. |
| **Purpose of Data** | Scaling stratum level carbon stock estimates to the project area level. |
| **Comments** | NA |

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| Data/Parameter | $U_x, sample$ |
|---|---|
| Units | Percent |
| Description | Sample uncertainty of carbon stock estimate $x$ at a 90% confidence level |
| Equations | Equation 5 |
| Source | **PU005** Section 5.1.1 |
| Value | NA |
| Justification of choice of data or description of measurement methods and procedures applied | See **PU005** Section 5.1.1 |
| Purpose of Data | Estimation of combined sample and model uncertainty. |
| Comments | NA |

| Data/Parameter | $U_{x,model}$ |
|---|---|
| Units | Percent |
| Description | Model uncertainty of carbon stock estimate $x$ at a 90% confidence level |
| Equations | Equation 5 |
| Source | **PT003** Equation 2 |
| Value | NA |
| Justification of choice of data or description of measurement methods and procedures applied | See **PT003** |
| Purpose of Data | Estimation of combined sample and model uncertainty. |
| Comments | NA |

| Data/Parameter | $Pl_n$ |
|---|---|
| Units | plants/ha |
| Description | Number of plants present of plant type $i$ |

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|---|---|
| **Equations** | Equation 6, Equation 7 |
| **Source** | Above-ground non-woody biomass samples |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Samples should be collected based on a random, stratified sampling approach. Stratification guidance can be found in Section 5.2.1.1. The sampling design should follow a scientifically recognised and rigorous approach, as published in the scientific literature[4], and appropriate for the geographic and physical context of the project area. Plot based or transect-based sampling is permitted. |
| **Purpose of Data** | Estimation of mean aboveground and belowground non-woody biomass per hectare in the non-woody biomass estimation strata. |
| **Comments** | NA |

| | |
|---|---|
| **Data/Parameter** | $Pl_n$ |
| **Units** | plants/ha |
| **Description** | Number of plants present of plant type *i* |
| **Equations** | Equation 6, Equation 7 |
| **Source** | Above-ground non-woody biomass samples |
| **Value** | NA |
| **Justification of choice of data or description of measurement methods and procedures applied** | Samples should be collected based on a random, stratified sampling approach. Stratification guidance can be found in Section 5.2.1.1. The sampling design should follow a scientifically recognised and rigorous approach, as published in the scientific literature[5], and appropriate for the geographic and physical context of the project area. Plot based or transect-based sampling is permitted. |

[4] Riquelme, R., Rumpff, L., Duncan, D. H., Vesk, P. A. (2022) Comparing grass biomass estimation methods for management decisions in a semi-arid landscape. Applied Vegetation Science.

[5] Riquelme, R., Rumpff, L., Duncan, D. H., Vesk, P. A. (2022) Comparing grass biomass estimation methods for management decisions in a semi-arid landscape. Applied Vegetation Science.

| | |
|---|---|
| **Purpose of Data** | Estimation of mean aboveground and belowground non-woody biomass per hectare in the non-woody biomass estimation strata. |
| **Comments** | NA |

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PT003 Guidance for the Use of Models Validated with Measurements in PV Climate Projects, Version 1.0. PV Climate Tool. Available from: https://www.planvivo.org/methodologies

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PT004 Identification of degraded and degrading land in PV Climate projects. Version 0.3. Available from https://www.planvivo.org/pt004

PU001 Estimation of baseline and project GHG removals by carbon pools in Plan Vivo projects. Version 1.0. Available from: https://www.planvivo.org/projects/certify-a-project/pvclimate/methodologies/approved-modules

PU002 Estimation of baseline and project GHG emissions from carbon pools in Plan Vivo projects. Version 1.0. Available from: https://www.planvivo.org/projects/certify-a-project/pvclimate/methodologies/approved-modules

PU004 Estimation of GHG emissions from leakage in Plan Vivo projects. Version 1.0. Available from: https://www.planvivo.org/projects/certify-a-project/pvclimate/methodologies/approved-modules

PU005 Estimation of uncertainty of carbon benefit estimates in Plan Vivo projects. Version 1.1. Available from: https://www.planvivo.org/projects/certify-a-project/pvclimate/methodologies/approved-modules

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# Appendix 1 Methods of Non-woody Biomass Measurement

This appendix provides further guidance on the methods for determining the aboveground and belowground non-woody biomass in sample plots

## Above-ground non-woody biomass measurement

Sampling above-ground non-woody biomass should be based on a random, stratified sampling approach. Stratification guidance can be found in Section 5.2.1.1. The sampling design should follow a scientifically recognised and rigorous approach, as published in the scientific literature[6], and appropriate for the geographic and physical context of the project area. Plot based or transect-based sampling is permitted.

It is recommended that the sample approach should be determined based on a preliminary assessment of vegetation type. Sampling the above ground non-woody biomass vegetation in each sampling area requires the clipping, sorting by species, drying and weighing of plants [7]. It is important to consider the coupling of the above-ground non-woody biomass sampling approach with that of the belowground non-woody biomass measurements (described below), so as to be able to appropriately develop the required models.

$$b_{AGNWB} = \sum_{p=1}^{n_i} Pl_n \times b_{AGNWB,pl}$$

*Equation 6*

$b_{AGNWB}$ Mean aboveground non-woody biomass per hectare in the non-woody biomass estimation strata (t d.m./ha)

$Pl_n$ Number of plants present of plant type *i* (plants/ha)

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[6] Riquelme, R., Rumpff, L., Duncan, D. H., Vesk, P. A. (2022) Comparing grass biomass estimation methods for management decisions in a semi-arid landscape. Applied Vegetation Science.

[7] Krak, K., Balsankova, T., Semberova, K., et al., 2025. Species-specific root-shoot ratios in a diverse grassland community. *Functional Ecology*, 39, 51-63.

$b_{AGNWB,pl}$ Mean aboveground non-woody biomass of plant type *i* (t d.m)

## Belowground non-woody biomass measurement

For all of the sampling methods described below- a stratified, random sampling approach should be taken to determine sample location (and likely coupled with the sampling of aboveground non-woody biomass (see Section 5.2.1.1). The number of required sample locations per strata depend on variance, with the power of the assessment increased with increased sample size[8, 9]) and must be sufficient to meet the uncertainty requirements of PU005.

As with the above-ground non-woody biomass sampling, it is important to differentiate the species sampled.

There is currently no academic consensus on a single, most appropriate method for fine root sampling, as this is dependent on the ecological context, capacity and resource access, time and finances. Thus, projects can select from any number of approaches described here, where appropriate. Appropriate scientific guidance and rigour should be followed for all approaches. It is recommended that a preliminary assessment on root depth should be implemented prior to the full sampling exercise[10]. Under all methods, fine roots can be separated using either dry picking or wet sieving methods.

**Core sampling**

Core sampling involves the use of a cylindrical auguring tool to extract a sample of soil, from which roots can then be separated out. Preference is for a larger diameter corer/auger of at least 10cm to allow for root sampling efficiency, and the sampling depth should cover the expected maximum depth of the fine roots where possible[6]. Larger corers can also avoid issues of soil compaction, which can result in an overestimate of fine root density which should be avoided[11]. If

[8] Bengough, A. G., Castrignano, A., Pages, L., van Noordwijk, M., 2000. Sampling strategies, scaling and statistics. In Smit et al. Root methods. *Springer,* Berlin, 147-173

[9] Berhongaray, G., King, J. S., Janssens, I. A., Ceulemans, R., 2012. An optimised fine root sampling methodology balancing accuracy and time investment. *Plant and Soil,* 358.

[10] Addo Danso, S., Prescott, C. E., Smith, A. R., 2016. Methods for estimating root biomass and production in forest and woodland ecosystem carbon studies: A review. *Forest Ecology and Management,* 359, 332-351.

[11] Park, B.B., Yanai, R.D., Vadeboncoeur, M.A., Hamburg, S.P., 2007. Estimating root biomass in rocky soils using pits, cores, and allometric equations. *Soil Science Society of America Journal*, 71, 206–213.

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the project is sampling soil using a core sampling method (as under **PT#SOC**), root samples can subsequently be separated and analysed from soil cores, thus presenting a time and cost saving option for projects.

**Pit sampling**

Pit sampling involves the digging of a pit of specific dimensions (dependent on the expected horizons needed, resource availability and presence of rocks in the soil) with removal of monoliths of soil from the pit walls. Root mass is then separated from the excavated soils[12].

**Ingrowth core method**

The ingrowth core method (or a modification there-off e.g. bags) involves the installation of permeable materials of a specific volume, into which fine roots grow over a specific period of time. Samplers should be installed at least 2 months prior to sampling, allowing in-growth of fine roots, and sufficient time should be allowed to pass to allow for maximum root establishment[6].

**Destructive, specific plant sampling**

This approach involves the direct destruction of plants through the excavation of their rooting systems. Sufficient plants need to be sampled to ensure that variance is accounted for. The number of plants per area (and the error associated with that value) must also be estimated (along with the error in that estimate), so that the average fine root density can be estimated.

$$b_{BGNWB} = \sum_{p=1}^{n_i} Pl_n \times b_{BGNWB,pl}$$

*Equation 7*

$b_{BGNWB}$ Mean belowground non-woody biomass per hectare in the non-woody biomass estimation strata (t d.m./ha)

$Pl_n$ Number of plants present of plant type *i* (plants/ha)

$b_{BGNWB,pl}$ Mean belowground non-woody biomass of plant type *i* (t d.m)

[12] Vadeboncoeur, M.A., Hamburg, S.P., Blum, J.D., Pennino, M.J., Yanai, R.D. and Johnson, C.E., 2012. The quantitative soil pit method for measuring belowground carbon and nitrogen stocks. *Soil Science Society of America Journal*, *76*(6), pp.2241-2255.



DRAFT

# Appendix 2 Data sharing

There are significant limitations in the availability of non woody belowground biomass data for grasslands and suitable models that would allow for estimation of carbon within this carbon pool. All projects using this methodology are therefore requested to submit raw data that they collect through their monitoring efforts, in particular on:

- Non woody belowground biomass measurements, SOC and bulk density from the same location
- Any other biomass measurements from the same location, if taken

Data should be submitted to the Plan Vivo Secretariat at the time of each baseline or monitoring report. A meta data file should be included which contains the following information:

- Project name,
- Sampling details (date, method)

The accompanying data frame would preferably be in a spreadsheet format with the following column headings:

| Project name | Country | Strata (if applicable) | Latitude of sample | Longitude of sample | Sample date | Non woody belowground biomass (g m-2) | Bulk density (g cm-3) | SOC (%) | *(Optional)* Non woody aboveground biomass (g m-2) |
|---|---|---|---|---|---|---|---|---|---|

It is expected that this data will be used by the Plan Vivo Standard, academics, project developers and others to develop models and inform project estimates, for the greater benefit of the field. All data submitted will be made available on request for research or project development purposes, with the caveat to users that all data owners are acknowledged in any further use of the data.