Multi-source inventory methods for quantifying carbon stocks and stock changes in European forests

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Reporting requirements of afforestation/reforestation joint implementation projects under the Kyoto Protocol and related data needs – a comparative case study: Hungary

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Summary:

This report details reporting needs and data requirements for monitoring carbon stock changes in afforestation/reforestation joint implementation (AR JI) projects. These requirements and data needs are developed based on approved methodology (i.e., the Good Practice Guidance for the Land Use, Land Use Change and Forestry sector). Moreover, it seemed likely that much information for the AR JI projects will be taken from national greenhouse gas inventories. Therefore, the analysis uses the information from the Hungarian national greenhouse gas inventories as a comparative basis. The Hungarian national inventory is used as an example, which other countries must adapt to their specific conditions.

The report analyses all information that may be necessary for monitoring AR JI projects. This includes general information, land related information, greenhouse gas emissions and removals considering all five carbon pools, and uncertainties. It draws information from all possible data sources, and provides suggestions as to when specific measurements or other project specific data should be obtained.

Note that this report is closely linked to report WP 8-D 8.1-ERTI of the CarboInvent project, which further details guidance on how project-specific information can be obtained in the monitoring.

	Affiliation/Function	Name	Date	Signature
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List of Abbreviations

A	Afforestation
AGB	Above ground biomass
BEF	Biomass expansion factor
BCEF	Biomass conversion and expansion factor
CAI	Current annual increment
CDM	Clean Development Mechanism
COP	Conference of Parties
CP	Commitment period
D	Deforestation
FM	Forest management
GHG	Greenhouse gas
GPG	Good Practice Guidance
JR	Joanneum Research
KP	Kyoto Protocol
LULUCF	Land Use, Land Use Change and Forestry
MA	Marrakesh Accords
NFD	National Forestry Database
NFI	National Forest Inventory
NIR	National Inventory Report
R	Reforestation
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

This report analyses reporting requirements and related data needs for current and potential methodologies of monitoring carbon stock changes, as well as emissions and removals of afforestation projects[1] under Article 6 of the Kyoto Protocol (KP). The basic approach of the analysis is that these requirements are contrasted to those for the national level greenhouse gas (GHG) inventories. The report focuses on the analysis of afforestation projects, thus, it is not the objective of this paper to develop all reporting and data requirements for the national GHG inventories under the KP and only those aspects of the national level GHG inventories are covered here that may be relevant for the project level monitoring. This report is closely linked to the report of deliverable 8.5 of CarboInvent (Somogyi, 2005).

The national level GHG inventories[2] under the KP should cover information on Article 3.3 afforestation and reforestation, as well as 3.4 forest management (FM) if elected. Note that, most probably, Hungary will not elect FM, however, it must submit annual reports on changes of carbon stocks in existing forests to the United Nations Framework Convention on Climate Change (UNFCCC). The basic approach in the paper was selected notwithstanding this fact, because other countries may elect FM on one hand, and Hungary, too, may use information from its national GHG inventory under the UNFCCC in projects, on the other. Thus, project monitoring and national level GHG inventory preparation may be interrelated.

As a methodological basis, the newly published Good Practice Guidance (GPG) for the Land Use, Land Use Change and Forestry (LULUCF, IPCC 2004) was used. Because of the importance of local conditions inherent in forestry, each project has its own challenges and only general guidance can be provided. This paper uses Hungary as case study to draw general conclusions[3].

1.1. Afforestation projects as tools for mitigating the greenhouse gas emission

Mitigation of climate change has received growing attention since it became evident that climate has been changing due to the emission of greenhouse gases. It also became evident that, because of the current trends in economies and human habits, no drastic changes in emissions can be expected at least in the short term. This was reflected in the commitments by Parties in the KP to reduce emissions by only a few percent. This emission reduction is a net one, since the Protocol allows for accounting of removals by forests.

[1] In addition to afforestations, projects under Article 6 of the KP can include forest management, agroforestry and others. This paper only analysis afforestation projects.

[2] In this paper, national inventory is the part of the NIR in which information is reported on the LULUCF sector.

[3] Any information on Hungary's choice must be regarded as preliminary, and are subject to change before her official report due later.

Although discussion has been going on the environmental soundness of applying forestry measures, relevant fora of the UNFCCC and the KP paved the way for applications. The COP-7 in Marrakesh approved the rules of Article 3.3, 3.4 and 6 measures, whereas COP-9 in Milan approved the rules for the LULUCF activities under the Clean Development Mechanism (CDM).

It is well known that, well conducted, afforestations produce many products and services. That afforestations and other forestry means can and should also be used in mitigating climate change is based on the basic belief in that

- managed forests, in many cases, are sinks at least in the short or medium term due to the dominance of their carbon fixing processes,
- other land uses may be less effective means of mitigation or even sources of emission,
- all types of measures in all sectors are necessary to use, including those in the LULUCF sector, if total net emissions from human activities are to be substantially decreased,
- there are only a few possibilities to remove carbon from the air, and afforestations are among the most important ones.

There are many types of managing forests, and that which of them are beneficial and which are not will only be shown by the experiences that we will gain in the years to come. It seems that establishing new forests can belong to the most effective means in the LULUCF sector to decrease net emissions. In any event, much depends on how accurately and feasibly the carbon cycle of afforestations can be monitored. Therefore, analysing methodologies and efforts to develop or replace them can play a crucial role.

1.2. Methodology, national GHG inventory and project monitoring

Methodology as used in this paper means the definition, identification, collection and processing of all data that are necessary for the estimation and reporting of emissions and removals. Other information will also be considered in this paper that is required to be reported by relevant UNFCCC documents. However, methods will only be addressed as far as they are relevant from a data requirement point of view.

National level GHG inventories for the LULUCF sector are to be prepared under the Convention and, from 2008, also under the KP. While the former aims at estimating emissions and removals in existing managed forests, the latter one contains supplementary information on emissions and removals for afforestation (A), reforestation (R), deforestation (D), and forests under forest management or revegetation, if these activities are elected. These GHG inventories are thus different in their information content. In this paper, we refer to national GHG inventory under the

KP when it is about reporting, but we draw on data requirements for both inventories, when it is about data needs.

Inventory and monitoring are activities that are similar in their objectives and methods. Both aim at estimating various characteristics of forest areas by using accurate, practical and cost-effective methodology. While the focus of inventory is rather on actual characteristics of forests at any time, e.g. stock volume, health, biodiversity etc., monitoring focuses on changes of characteristics over time. For the purposes of the analysis in this paper, inventory refers to the national greenhouse gas inventory, and includes Article 3.3 areas, if not stated otherwise, whereas monitoring refers to estimating carbon stock changes, emissions and removals over time in the context of afforestation projects under the KP.

1.3. General comparison of the national and project level reports

The general purpose of both compiling the national GHG inventory and of monitoring in projects is to report estimates of emissions and removals. However, there are many differences between reporting at the national level and at the project level. While there are many methodological and other obstacles, preparing the national inventories can be relatively simple, since many countries have more or less developed traditional forest inventories with established methodology and databases that could also be used for the GHG inventories. In contrast, project monitoring requires a lot of local data, but it could be simplified if data and other information from the national inventories could be used. There are only a few projects in the implementation phase, thus, there is limited experience in project monitoring.

The information content of national level and project reports is summarized and compared in **Table 1**.

Table 1. General comparison of national forest GHG inventories and monitoring of afforestation projects.

Aspect of comparison	National GHG inventories	Monitoring of Article 6 afforestation project
General purpose of emission and removal estimation	To meet reporting needs at the national level.	• To meet reporting needs for the country. • To meet reporting needs of the contract between the host and customer country, • To meet reporting needs possibly between owners and any of the countries.
Method of assessment of the total forest area	Area may be assessed by a wall-to-wall system or by a sample based system, in which a project area, or its parts, may not be represented separately.	Special and detailed knowledge is required on the complete area of the project, which may not be available from the national inventory, because the location or the scale of the sampling units of the inventory do not overlap with the project area
Geographical locations[4]	Administrative and/or ecological units of the country are used, which may cover nationally important areas.	Detailed representation of the project area is required not as a geographical location, rather, as a project. The whole project area or its parts may be part of a geographical location of the national inventory.
Pools to be assessed (note that all pools must be assessed at	The estimation of pools depends on the geographical locations chosen that are relevant for the country level. A pool that is relevant in the project area may not be	All five pools must be reported for the project if they are a source, even if those pools are not reported in the national inventory.

[4] Geographical locations must be reported under the KP and refer to the boundaries of the areas that encompass units of lands subject to Article 3.3 and lands subject to Article 3.4 activities (FCCC/CP/2001/13/Add.3 p.22 paragraph 6b)).

Aspect of comparison	National GHG inventories	Monitoring of Article 6 afforestation project
both levels that are not a source)	estimated in the national inventory.	
Accuracy	Limited by resources for preparing the inventory, as well as accessibility and variability of various parts of national forests. May be low for the project area even if emission and removal estimates for the project area can be developed from national level data or by methods, because they are usually tailored to larger scales that are adequate for the national level.	May be higher than in the national inventory due to higher requirements (set by contract), more resources, as well as easier access and the lower variability of forest characteristics within the project boundary.
Monitoring intensity, sample design	Tailored to size and heterogeneity of larger areas (e.g. strata) within geographical locations.	Tailored to the size and heterogeneity of project area.
Sampling/Monitoring frequency	Ranges from rare to a few years.	Ranges from one year to a few years. The surveys are not necessarily done in years when the surveys for the national GHG inventory are done.
Operation and supervision	By national inventory organizations.	Special teams may be necessary.

It can be concluded from the above table that, in all probability, reporting on projects will require more intensive and more detailed data collection than reporting on national GHG inventories, but some data from the national inventory may be used in projects.

1.4. Hungary as test case

In Hungary, national GHG inventories have been prepared since 1995. Although the methodology of these inventories has been developed over time, the basic approach, assumptions and estimating procedure have remained the same. In contrast, no afforestation has taken place so far in the country. However, the annual rate of afforestations (5-15 thousand ha a year in the last several decades) is substantial, which also represents the order of magnitude of the total area of a possible Article 6 afforestation project. Therefore, it seemed optimal to choose Hungary for testing the methods of the new GPG within the CarboInvent project. In lack of a real Article 6 project, only theoretical possibilities can be tested. However, a virtual test site has been created with real-world forest stands to test as many elements of the monitoring methodology as possible.

This virtual test site was also used to develop data needs, and the analysis below records the current state of data availability in Hungary with some possible or planned improvements in the next few years to come. However, even if a real project had been used, new projects in Hungary or any project in other countries may deviate from this case and require special data. The requirements shall always be met by data that can be obtained in a feasible, practical and economic way. Note that specific data used in the national GHG inventory is not included here, and can be found in NIR-H (2003).

2. Generic information to be reported

The KP, the MA and other relevant legal texts specify what is to be reported under the KP. In addition to land related information, and information on emissions and removals there are many other pieces of information that are to be reported. All this information is to be reported in the National Inventory Reports (NIR), but will apply for projects as well. This chapter gives a summary of them.

2.1. Information to be reported before the first commitment period

The MA require that Parties report their forest definition in the context of the KP. The definition will be common for all 3.3 and all forest related 3.4 activities, and will be provided by selecting single minimum values for land area, width of forest area, tree crown cover and tree height. In a strict sense, this is not an emission or removal related information, however, they are methodologically important as they affect area determination, the detectability of land use change, and the estimation of emissions and removals. Information on the forest definition must be reported prior to 1 January 2007 or one year after the entry into force of the KP for that Party, whichever is later, and it cannot be changed during the first Commitment Period (CP). For Hungary, the most likely elements of the definition are given in **Table 2**.

Note that other information is also to be reported before 2007, but it does not affect inventory or monitoring methodology, therefore, it is not discussed here. (For details on all information to be reported see Table 4.2.4.A and B in chapter 4.2.4.3.1 of the GPG.)

Table 2. The possible definition of "forest" in Hungary for the national GHG inventory reporting under the KP. Note that the single minimum width of forest area is not required by the MA, but it is regarded good practice to report it (IPCC 2004). Note also that none of the values in the table have been officially approved as yet.

Reporting requirement	Information that will most likely be reported by Hungary
A single minimum land area	.15 ha
Single minimum width of forest area	10 m
A single minimum tree crown cover value between 10 and 30 %	30 %
A single minimum tree height value between 2 and 5 metres	5 m
Justification that such values are consistent with the information that has historically been reported to the Food and Agriculture Organization of the United Nations (FAO) or other international bodies, and if they differ, explanation why and how such values were chosen	For Hungary, the above figures are consistent with the information reported to FAO (see TBFRA 2000, p. 79)

2.2. General information to be reported for the first commitment period on methods and approaches used to estimate emissions and removals

2.2.1. Description of methodologies used

The description of methodologies used is of high importance, because it provides relevant additional information on the consistency, comparability, completeness and accuracy of emission and removal estimates. All this and other information is also required to be reported to meet the requirements of the KP and the MA for transparency.

2.2.1.1. National GHG inventory level

At the national level, Hungary recently reported methods used in national GHG inventory in her latest NIR (NIR-H 2003). This paper describes some methodological elements in a more detailed way (see Chapter 4, Information on carbon stock changes, as well as emissions and removals).

2.2.1.2. Project level

The description of methodology used for any specific project will be required by the contract between project participants. It should at the minimum detail all data requirements, methods, factors etc. described here.

2.2.2. Justification when omitting any carbon pool

Although the MA requires that carbon stock changes be reported in five pools (above ground biomass, below ground biomass, dead organic matter, litter, soil), it allows Parties not to report these changes for a pool if it can be verifiably demonstrated that the pool is not a source. All pools can be sources and sinks depending on actual processes, as well as temporal and spatial scales. In addition, monitoring of carbon stock changes of pools may be resource intensive compared to the expected rate of change. Therefore, this option will be used at both national and project level, however, in different ways. In any event, this option can only be taken after all assumptions and available data have been considered. Therefore, we analyse in Chapter 4, Information on carbon stock changes, as well as emissions and removals whether when this option can be taken in the next sections for each pool.

2.2.3. Information on indirect factors on greenhouse gas emissions and removals

The MA requires that:

“Information should also be provided which indicates whether or not anthropogenic greenhouse gas emissions by sources and removals by sinks from land use, land-use change and forestry activities under Article 3 paragraph 3 and elected activities under Article 3 paragraph 4 factor out removals from:

(a) Elevated carbon dioxide concentrations above pre-industrial levels;

(b) Indirect nitrogen deposition; and

(c) The dynamic effects of age structure resulting from activities prior to 1 January 1990.”

This requirement has become known as the “factoring out” issue. The IPCC Meeting on Current Scientific Understanding of the Processes Affecting Terrestrial Carbon Stocks and Human Influences upon Them, which was recently organised to try to assess whether factoring out can be achieved, issued a scientific statement (IPCC 2003) saying: “The scientific community cannot currently provide a practicable methodology that would factor out direct human-induced effects from indirect human-induced and natural effects for any broad range of LULUCF activities and circumstances.” Consequently, it is not clear at the moment what methodology will be accepted by the international community to take care of the factoring out issue. Discussions are ongoing at SBSTA. Potential project participants should follow these discussions, because factoring out may be important in projects, and also because factoring out and estimating baselines in projects may also require similar methods and/or data.

2.2.4. Changes in data and methods

This topic is not analysed here, as it has no direct relations to data requirements. It must however be noted that, especially in countries where transition of economic and political systems have been ongoing, both data availability and methodology may change substantially in several years to come. An example for this is privatization of forest land, due to which some data cannot be obtained as easily or as accurate as before. This may have an effect on data availability over time, as well as on the accuracy and consistency of emission and removal estimates.

2.2.5. Other issues

The year of the onset of the activity, i.e. the year of the beginning of the project is also to be reported. All carbon stock changes and GHG emissions and removals due to project activities must be reported, and they may begin before trees are planted. A project may start with planning and other activities during which the baseline estimates would apply to the project area. In Hungary, this is followed by a site preparation which may result in emissions from the soil. Much depends on the technology of the soil preparation: while subsoiling does not open the surface much, ploughing brings layers with much carbon to the surface, where this carbon is quickly emitted due to oxidization. Therefore, it is of high importance to document the technology used.

2.2.5.1. National GHG inventory level

In afforestations since 1990, usually ploughing was used. A study is under way in the project test site to measure carbon stock changes in soils due to afforestations. Until data are obtained, the argument can be used that, at least on average, the emissions due to soil preparations have been by far offset by increases of soil carbon due to plant activity. Therefore, there is not need to report on the soil carbon pool in Hungary. Also, it is enough to state that the year of the onset of the activity is the same as the year of planting, which is indeed the same in most afforestations.

2.2.5.2. Project level

The year of the onset of activities in the afforestation project test site in Hungary was usually also the year of planting. This is because soil preparation is usually done not long before planting, or even together with planting to avoid competition from weeds. Nevertheless, data from ongoing measurements may be used in future to provide additional information on the importance of reporting the onset of soil preparation more specifically.

3. Land related information

3.1. Forest area

In general, the definition of the forest area is the same in both national reports and projects, and involves the definition of "forest" (see above in chapter 2.1, Information to be reported before the first commitment period).

3.1.1. National GHG inventory level

In the context of the NIR, the forest area includes all managed forests, which is taken the same as all forests, since only a very tiny fraction of all forests could be classified as unmanaged. In the context of projects, all forests within the project boundary should be considered for both the project, as well as the baseline scenario.

For Hungary, only that area is used for estimations in a year that is actually covered by forest, i.e. for which the area of the species could be determined. Other areas like roads, nurseries, croplands to feed game etc. that are managed by forestry companies and that are not occupied by trees are not taken into account. Forest area data is stored in the National Forestry Database (NFD) for each stand whose average size is approximately 6 ha. For each stand, various characteristics are assessed in addition to the area, which make it possible to calculate the area occupied by each species.

3.1.2. Project level

Forest area of a project may be received from the NFD, however, it is more likely that the area actually afforested each year is assessed by a crew of any of the project participants, or by a contracted crew. By inspecting the afforested area, the crew can also record whether the planned tree species were used, or whether there is any departure from the project plan.

3.2. Geographical locations, and identification of "units of land" and "lands"

The MA requires that "the geographical location of the boundaries of the areas are reported that encompass:

(i) Units of land subject to activities under Article 3, paragraph 3;

(ii) Units of land subject to activities under Article 3, paragraph 3, which would otherwise be included in land subject to elected activities under Article 3, paragraph 4;

(iii) Land subject to elected activities under Article 3, paragraph 4."

For Article 6 projects, the recording and reporting of project boundaries is required. Information on the methodological choices used for reporting is also to be reported at both levels. However, because of their different nature, different data are necessary at the national and at the project level.

Data, its source and level of detail of reporting relevant land related information for the national GHG inventory of Hungary and for the project test site can be found in **Table 3.**

Table 3. Data, its source and level of aggregation for reporting land related information both in the national GHG inventory and in projects.

Data to be reported	**National GHG inventory (Hungary)**			**Project level (Hungarian test site)**		
	Data source	**Primary level of data collection for the national GHG inventory**	**Lowest level of aggregation of reporting**	**Data source**	**Primary level of data collection**	**Lowest level of aggregation in reporting**
Species and age	NFD	Species or species groups		Project specific survey, or NFD	Stand	Stand
Forest area	NFD	Species or species groups and age classes	Species and age class	Project specific survey, or NFD	Stand	Stand

3.2.1. National GHG inventory level

The GPG defines three approaches to representing land areas: one that only identifies the net changes in the areas of different land-use categories; one that focuses on land-use transitions, and one that explicitly tracks land based on sampling approaches, a grid system, or a polygon system within the geographic boundaries, which have resulted from the stratification of the country. The GPG also defines two reporting methods: broad area identification and complete area identification. According to the GPG, only approach 3 is regarded as good practice for KP reporting, but both reporting methods can be good practice under certain condition.

According to the current Hungarian Forest Law, effective since 1996, all afforested land is under the land use type of “forest” right after the afforestation is deemed successful, which may take several years after planting. Land in the “forest” land use type has long been identified in a detailed system of stands, the average area of which is around 6 ha. These stands or any aggregate of them (e.g. by administrative units) can be regarded as “units of land” or “land”. Digital maps are currently available over 90% of all forests, so, until the beginning of the CP, it will be possible to draw maps of any area that will need to be reported. The area of existing forest is continuously assessed by checking the area of the compartment once in every decade using aerial photographs and field survey if necessary. Therefore, Hungary will apply reporting method 2.

Concerning A and R land, tracking back of areas that will have been afforested and reforested since 1990 could mostly be made in the commitment period, because detailed databases exist due to relevant related regulations, the developed forest management planning system, and also because data may exists on the subsidies of the afforestations. In contrast, all deforested land, registered as one of many “non-forest” land use types in or after the year of deforestation, may only partially be tracked at the moment, and further efforts are needed to obtain accurate estimates.

3.2.2. Project level

The exact area of all afforested land in a project level needs to be known for the monitoring, but also of course for the implementation of the project itself. All project participants, including land owners want to know e.g. land is accurately allocated for and whether afforestation is carried out exactly according to the contract. In addition, forest authorities may also have right or duty to check the fate of land and the stands that are established.

In Hungary, “forest” as land use category is administered by the National Forest Service. According to law, a forest management plan must be prepared for each stand larger than 0,15 ha. This plan must include a map. As already mentioned above, maps are available for all forest area and almost all such maps for the existing forests are already digitized. Information on the boundary can be drawn from these maps if they are already available. Alternatively, or if no such maps are available for any part of an afforestation project, it may be necessary to obtain information on the corner points of the polygon bordering the project area, and produce (digital) maps, using GPS or any other appropriate tehcnology.

3.3. Spatial assessment unit

3.3.1. National GHG inventory level

The special assessment unit is used for the determination of afforestation and reforestation, and it cannot be larger than 1 hectare. In Hungary, forest area is determined on a stand-wise basis, however, stands are inspected for crown closure during preparation of management plans, or when a harvest operation is done, or after major natural disturbance. If it drops below 30 percent on an area larger than 1 ha[5], then the area has to be reforested.

3.3.2. Project level

Projects in Hungary will also classify as forests, and the same Forest Act and other laws and regulations will apply, so the spatial assessment unit in projects cannot be larger than 1 ha, either. However, if project participants so agree, it can be smaller, but most likely any smaller value could be regarded as impractical, for applying smaller values would imply high increase of monitoring costs with modest or no increase in achieved accuracy.

4. Information on carbon stock changes, as well as emissions and removals

Information on the carbon stock changes, and emissions and removals must be provided for five pools: above ground biomass, below ground biomass, deadwood, litter and soil. At the national level, Hungary has only reported carbon stock changes in the above ground biomass pool so far. This was because data were only available to estimate changes in this pool. Since all forests in Hungary are regarded as managed, the above ground biomass is going to change, and its monitoring will continue. However, methodology should be further developed to estimate other pools, too.

4.1. Above ground biomass

4.1.1. National GHG inventory level

It can be shown that the above ground biomass (AGB) of the forests of Hungary has been growing for decades, and is going to further increase for at least a decade. On one hand, this is because relatively large afforestations have been made in the last several decades (about one third of all forests were established after World War I), and the

[5] Not yet officially approved value.

afforested stands are in their most productive age. On the other hand, while timber harvest has increased, this increase never exceeded the continuous increase of total increment during the same period.

Carbon stock changes in the AGB pool can be estimated relatively easily because of the detailed forest inventory database. The data of all forests of the country are stored in the NFD. It is based on a continuous inventory, in which about 1/10-1/12 of all forests are surveyed each year, while the rest is updated using yield tables and annual harvest and regeneration data. Many aggregated data are public for the country for each year since the 1980's. Thus, reporting has always been and will continue to be done using Tier 2 methodology, which is based on a methodological framework suggested by IPCC and country specific data.

Hungary has so far used the default, or process based, method[6]. This methodology to estimate carbon stock changes in the AGB pool is based on the following equation:

$$\Delta C_{AGB} = (BG - BL) * CF \qquad (1)$$

where

ΔC_{AGB} = carbon stock changes in the above ground biomass (AGB) pool;

BG = biomass growth;

BL = biomass losses;

CF = carbon fraction of (dry) biomass.

Biomass growth in any aggregate unit *i* can be estimated by

$$BG_i = I_i * BECF_i \qquad (2)$$

where

I_i = (net) above ground tree volume increment in aggregate unit *i*;

$BECF_i$ = the combined expansion and conversion factor for living trees, for aggregate unit i, to estimate (dry) biomass from (fresh) volume.

Biomass losses in any aggregate unit *j* can be estimated by

$$BL_j = (H_j + F_j + S_i + O_j) * BECF_j \qquad (3)$$

where

[6] Most likely, the country will use the stock change method in future inventories. The stock change method may be more appropriate for projects, however, due to lack of experience of using this method at the country level, the default method is demonstrated here. Note that, although the methods differ concerning the volume data, they may use the same expansion and conversion factor or function information.

H_j = volume of commercial tree volume in aggregate unit *j*;

F_j = volume of fuelwood in aggregate unit *j*;

S_j = volume of slash in aggregate unit *j*;

O_j = volume of other wood removed in aggregate unit *j*;

$BECF_j$ = the combined expansion and conversion factor for harvested trees, for aggregate unit j, to estimate (dry) biomass from (fresh) volume;

Total carbon stock changes for all aggregate units can be estimated by

$$\Delta C_{AGB} = [\ \Sigma_i (I_i * BECF_i) - \Sigma_j (H_j + F_j + S_i + O_j) * BECF_j\ ] * CF \qquad (4)$$

where

Σ_i = sum of gains due to net tree growth in aggregate unit *i*;

Σ_j = sum of losses of tree and other biomass due to harvests and other disturbances from the forest in aggregate unit *j*.

The aggregate units are any categories for which reliable and accurate estimates are available. These can be by forest type, climatic zone, species, age class etc. They may be the same for both gains and losses (*i* = *j*), but *i* and *j* are different in Hungary, because data on AGB in the published statistics are available by species and yield class, whereas harvest data are only available in some cases in species groups.

The aggregation for reporting under the UNFCCC is at the species level, although higher level of disaggregating would be possible. The data required by equation *(1)* above is summarized in **Table 4.** and the following sections.

The definition of all terms in the above equations must also be specified in reports for transparency, completeness and accuracy. The definitions are also included in the following sections, in which information is also given as to the specific data and reporting requirements in Hungary.

Table 4. Data, its source and level of aggregation for reporting carbon stock changes in the AGB pool for the Hungarian forests both in the national GHG inventory and in projects. Note that, for projects, either volume growth or biomass growth can be estimated.

Data to estimate variables in equation *(1)*	**National GHG inventory (Hungary)**			**Project level (Hungarian test site)**		
	Data source	**Primary level of data collection**	**Lowest level of aggregation of reporting**	**Data source**	**Primary level of data collection**	**Lowest level of aggregation of reporting**
Species, age, tree height	NFD	Species or species groups		Project specific survey, or NFD	Stand	Stand
Specific volume growth rate	(not used in the emission and removal estimation, but recalculated from volume growth and area)	Species or species groups	Species or species groups	Yield tables (as in NFD), or field survey at two consecutive occasions	Stand or plots within stand	Stand
Volume growth	NFD (which uses yield tables based on age, and measured height)	Species or species groups	Species for the whole country	[Calculated from stand area and specific volume growth rate]		Stand
Biomass conversion and expansion factors for living trees	Wood density from professional literature	Species or species groups	species	As in NIR, or local measurements	Species	Species

Data to estimate variables in equation *(1)*	**National GHG inventory (Hungary)**			**Project level (Hungarian test site)**		
	Data source	**Primary level of data collection**	**Lowest level of aggregation of reporting**	**Data source**	**Primary level of data collection**	**Lowest level of aggregation of reporting**
Biomass growth	(calculated from volume growth and biomass conversion factor)		Species	Either calculated from volume growth, or measured at field surveys at two consecutive occasions	Stand or plots within stand	Stand
Volume of commercial harvest	NFD	stand	Species and species groups	NFD or local survey (not needed if volume stocks are surveyed at successive occasions)	stand	stand
Volume of fuelwood	NFD	stand	Species and species groups	NFD or local survey	stand	stand
Biomass expansion and conversion factors for harvested volume	Same as for tree growth	Same as for tree growth	Same as for tree growth	Same as for tree growth	Same as for tree growth	Same as for tree growth
Carbon fraction of wood	IPCC default	N/A	(Same value for all species)	IPCC default	N/A	(Same value for all species)

4.1.1.1. Biomass and its growth

By biomass, only the (above ground) biomass of trees is meant. Although forests are more than just the trees, no data is collected in the NFI in Hungary on shrubs or the herb layer, since their amount is deemed very small compared to the biomass of trees. Net biomass growth is thus defined as the net increase of tree biomass growth. Concerning trees, all above ground parts are considered, including small branches and leaves.

The estimation of aboveground tree biomass is usually not done by direct biomass measurements. This is because it would require intensive sampling and field measurements. Rather, tree volume estimates are used as proxy values that are available from the forest inventory, and these volume estimates are then converted to biomass by using biomass expansion and conversion factors (see below).

4.1.1.2. Tree volume and net volume increment

In Hungary, tree volume is generally defined as the total volume overbark of all aboveground parts of the tree, including small branches and leaves. This definition is different from that in many countries. Volume functions and tables for all species were recently published by Sopp & Kolozs (2000). The latest volume function, developed by Somogyi & Csiha (2002) for 'Pannonia' hybrid poplar, a candidate for afforestations in Hungary, is the only volume function that only estimates volume for the thick part of the stem with a top diameter of 7 cm.

Specific current volume increment of unit forest area (m^3/ha*yr) by species, age and yield class is estimated in Hungary by using standard yield tables. For species with no yield tables, data of other tree species of similar growth pattern is used. The yield tables were developed by the Hungarian Forest Research Institute; references to and some data of all the latest yield tables can be found in Somogyi (2002).

Note that the specific volume growth values are not used directly in the GHG inventory estimates. The specific values are used in the National Forest Inventory (NFI) to derive increment data for all compartments, which are then aggregated for the whole forest area. Specific volume values are recalculated and reported for these values only for transparency reasons. Likewise, specific biomass growth is not used, either, but could be recalculated from (total) biomass growth and forest area.

It must also be added that mortality is either not included, or estimated rather conservatively in the yield tables, a discount factor of .95 is used for all species in order to account for natural losses. Quite naturally, the intensity of mortality varies over time: during periods of diseases, like oak disease, and due to other natural disturbances mortality is higher than average, but there are periods when, due to favourable wheather and other conditions, mortality is low. This variation is not captured by the NFI, either.

Some variation is also characteristic of the volume increment due to the variability of climate, and the yield tables are not able to capture this variation, either. This is one reason why the estimated increment values are supposed to be checked (validated) against data from other methods. In Hungary, total increment for the whole country was checked against measured change of volume stock (NIR-H 2003, Somogyi 2004), the result being satisfactory at the country level, but less reassuring at the species level.

4.1.1.3. Biomass expansion and conversion factors for living trees

The definition of these factors is closely related to the definition of tree volume and biomass. The expansion and/or conversion can occur in one step, or in several steps. In any event, the exact definition of the factor(s) should be reported.

In Hungary, it follows from the definition of volume that no expansion factor is needed. For conversion, the density of wood (specific weight of dry wood) is used. This is a rather simple way of converting, however, it slightly overestimates biomass, because the same value is inherently used for all parts of the tree, i.e. the wood and the bark, thick and thin branches, although the density of the non-wood parts is lower than that of wood.

It also follows from thisthat both the expansion as well as the conversion factors are also age and/or size dependent. Furthermore, different factors may be needed to convert volume increment to biomass increment than to convert volume to biomass. For more accurate estimations, this should be taken into account. In Hungary, the dependence of wood density on size or age is not known at the moment, therefore, the same specific wood density is used for all age classes for conversion of increment.

4.1.1.4. Commercial harvest

Harvest data in Hungary can most often be obtained from forestry or other national statistics. These statistics include the volume of all parts of all trees that are removed. The volume of commercial harvest is estimated from these statistics by using appropriate factors.

Note that, in Hungary, some one fifth of all tree volume harvested remains in the forest as slash. This is taken into account in the harvest statistics so that the volume of roundwood measured at roadside loading stations is converted back to total aboveground volume removed and that is registered in the statistics.

4.1.1.5. Fuelwood volume, other wood removed and slash

In Hungary, fuelwood harvested by forestry companies is registered the same way as commercial harvest. Therefore, estimates on its amount are available (like with the commercial harvest volume, this amount is calculated from the total statistics by using appropriate factors). The amount of other fuelwood collected in small amounts by private people is partially accounted for, due to lack of estimates, in the discount factor referred to above at the specific volume growth, and partially by reporting some volume under “other wood removed”.

The category “other wood removed” is used also to account for the total volume of trees that are removed from forests in any other way, and from which greenhouse gases are emitted in the year of removal. This volume includes mortality that is not accounted for in the net volume increment, or forest fires in compartments where neither updating nor new survey could account for changes in volume stocks. It is based on simple expert judgment.

Slash wood volume is the total volume of parts of harvested trees that are left in the forest as slash. It is estimated for the GHG inventory from the amount of total harvested volume by using factors which are long-term country averages.

4.1.1.6. Biomass conversion and expansion factors for harvested trees

It is quite possible that different factors must be used for harvested trees than for living ones. This is because the size and form of harvested trees differ from those of living trees. In Hungary, however, the same conversion factors are used for harvested wood and for living trees due to lack of more specific information.

4.1.2. Project level

Monitoring at the project level usually requires data with similar definitions, but the data must often be obtained from different sources. In general, it must be pointed out that project level methodology and data acquisition also depends on the development of the project over time. It means that, in contrast to the inventory of all the forests at the national level, the amount of which may increase only slowly (in Hungary, at a rate of 0.3-1% per year), the area of the total forests of the project may increase very quickly in the first years (e.g. the area may double in some years), which also involves increase of diversity at least in terms of age, but possibly also by species and site. This may have an effect on the methodology (sampling) and the collection of data.

Another basic difference between data required by monitoring of projects and national GHG inventories is the method of estimation of change in biomass. While it is possible to use similar methodology in both projects and the national GHG inventory, i.e. to use the same equation, it is more practical to use the following equation:

$$\Delta C_{AGB} = [\ \Sigma_i\ BG_i - \Sigma_j\ (H_j + F_j + O_i + S_i) * BECF_j\ ] * CF \qquad (5)$$

The strata denoted by i and j can be the same, but can be different here, too. Again, details are given below by data variables in the equation.

4.1.2.1. Biomass

For biomass at project level it is likely that the same definition applies than at the national level. However, it is possible in some projects that shrubs and bushes are also included. In Hungary in general, and especially in the project test site, no shrubs and bushes occur in afforestations at least for decades, so only trees are included in the biomass.

The least field work intensive but also the least accurate method to estimate biomass is to use the same volume functions and biomass conversion factors that are used at the country level. However, as noted above, it can be considered in projects that biomass is not estimated through measuring or estimating volume and multiplying it with biomass expansion and conversion factors, but by directly measuring it. The advantage is obvious: more exact data with even less effort. It can be considered that a single-tree biomass equation is established between biomass and easily measurable variables like breast height diameter, and/or height:

agb = f(bhd) or *(6)*

agb = f(bhd, th) *(7)*

where

agb = above ground biomass,

bhd = breast height diameter (diameter at 1,3 m above ground)

th = (total) tree height.

This option must be selected especially if a tree species, clone, variety etc. is used for afforestation for which volume function and/or biomass expansion/conversion factors are not available. This is, because measuring sample trees is inevitable in these cases anyway, but the measurement of volume of sample trees, which is necessary to establish conversion factors and to estimate uncertainty, can be time consuming. If the biomass of the sample trees is directly measured instead, more trees could be included in the sample, which may make it possible to take samples more efficiently, e.g. across several variables influencing biomass like age, spacing and site.

4.1.2.2. Tree volume

If the estimation of volume is necessary in the project, it can be done using the same volume functions that are applied at the country level. Considering that the objective of afforestations will not only be carbon sequestration, but often also wood production, it can happen that information on volume is required anyway, and even that specific, more detailed information is required on merchantable volume. If there is some evidence that volume functions only provide inaccurate, or biased, estimates for the project area, it may be necessary to develop local volume functions. In order to check the accuracy of volume functions, a proper sample is necessary. For young trees, the available volume functions may not provide accurate readings or no readings at all, in which case measuring tree volume on a sample basis may also be necessary. In case volume is estimated instead of biomass, it may be necessary to take a sample for biomass expansion factors.

Two estimation methods must be distinguished for estimating volume of stands. The simpler, but less accurate method involves measuring bhd and th of tally trees, and volume of these trees is estimated using volume functions (the same as mentioned above). More field work is required if volume is to be directly measured on each tally tree. A combined method is the most practical, when local volume functions are developed by using sample trees, and these local functions are applied to all tally trees, for which only bdh and total tree height are measured. In Hungary, this combined approach should be regarded as one of the preferred monitoring methodologies in projects.

4.1.2.3. Specific net volume increment and specific biomass growth

Data on specific biomass growth can be obtained by using various methods, thus, data needs and reporting requirements vary. Unlike at the country level, it can directly be estimated in projects and multiplied by forest area to get the total biomass growth estimate. The most important methods and data sources are the following:

- *Yield tables or functions*. This is the same method as used at the country level. The obvious advantage is that the use of the tables is relatively simple and cheap. Disadvantages include that the estimation may not be accurate for the project area, little is known on the accuracy, no data may be available for young stands, and the fixed curves of the functions cannot reflect any temporal changes in the growth patterns due to changes in the environment over several years. In Hungary, the same yield functions could be used that are mentioned above at the country level. Depending on actual cases, mortality can be taken into account by applying a case specific discount factor (see above at the country level). Since stands are intensively managed (more intensively than in slow growing forests of indigenous species), thus, mortality rate is very low, and no discounting is necessary.

- *Measuring volume stock changes*. By measuring volume stocks at two consecutive occasions, (net) increment can be calculated as the difference between the two volume stock estimates. The advantages include that a measure of accuracy can also be obtained. However, the uncertainty can remain high if sampling density is low, or if the time elapsing between the two measurements is short. Also to be noted is that, if the stand was thinned between the two surveys, the measured stock changes already include the amount of volume thinned, thus, all terms in the biomass loss part of equation (5) must be set to zero to avoid double accounting.

- *Measuring increment by annual ring analysis.* This is a theoretical option, however, it is not suggested because of the large measuring requirements and relatively low accuracy. This method can only be used for checking accuracy for past periods during which no thinning took place. This method cannot be used if tree height is also required for the method that is used to estimate volume or biomass.

- *Direct measuring of changes of biomass*. This is the same method as measuring volume stock changes with the exception that biomass is measured instead of volume. This method should be preferred whenever possible, because this yields the most accurate biomass estimates. However, it is not feasible to measure the biomass of all tally trees. Therefore, since there are no biomass functions at all, not even speaking of local ones, such functions should be developed, in which the independent variables are bdh, and preferably th. After such functions are developed, the bdh and th measurements of the sample trees can be used for stock volume and volume increment estimates, too, thus, data for the traditional forest inventory can also be produced, which may decrease monitoring costs.

4.1.2.4. Biomass expansion and conversion factor for the living trees

For the definition of these factors, if needed, the same considerations must be taken as in the national GHG inventory (Chapter 4.1.1.3).

The use of such factors depends on the method of estimating changes of biomass. If this is directly estimated as is suggested above, no expansion and conversion factors are necessary. If volume increment is used as a proxy variable, care must be taken to check the definition of volume, i.e. to check what value is to be converted to biomass. If volume definition other than that given in Sopp&Kolozs (2000) or Somogyi&Csiha (2002) is used then special BECFs must be developed.

4.1.2.5. Commercial harvest and fuelwood volume

Since any removal of trees, including removal of commercial timber of fuelwood, can considerably decrease biomass, harvest data must be accurately monitored unless the stock change method is used (see above under 4.1.2.3, Specific volume increment and specific biomass growth). Data can either be obtained from forest inspectorates, or from owners. However, unofficial data from forest owners can be underestimated, or associated with unknown high uncertainty. More accurate data can be obtained from permanent, not visibly marked plots.

4.1.2.6. Biomass conversion and expansion factors for harvested trees

The same applies here as at the national GHG inventory level.

4.2. Belowground biomass

Because of its spatial and temporal variation, and because it is very difficult to access, belowground biomass is extremely difficult to estimate. Although similar equation could theoretically be used as *(5)* for the estimation, it does not seem to be practical even in projects. Therefore, other methods and considerations are necessary.

4.2.1. National GHG inventory level

The development of below ground biomass of trees follows an age dependent pattern, but depends on many factors like site. The above ground biomass has been increasing in the forests of Hungary, and is likely to be increasing at least until the end of the first CP, due to the current age structure of stands and due to the continuous increase of the forests in the country (**Fig. 1**). Considering also that the root system of the harvested trees becomes dead after harvest, it can be inferred without a detailed analysis that, the below ground pool of the forests of Hungary is increasing, i.e. it is not a source, and it is not necessary to estimate its carbon stock changes. As to the exact size of this carbon stock and its change, further analysis is necessary with detailed calculations. For these calculations, at least average data of belowground biomass from the scientific literature would be needed by species, site and age. Approximate estimates can be obtained by using the model called CASMOFOR (Somogyi, 2002) which was developed with the aim to model the carbon cycle of afforestations in Hungary, but which could also be applied for existing forests.

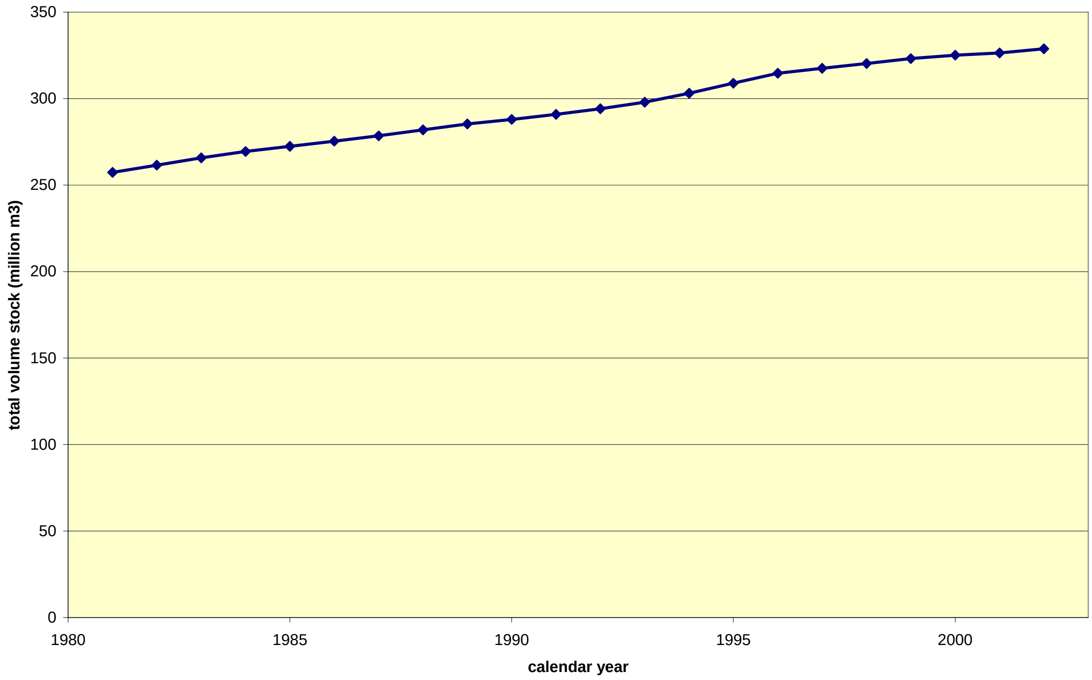

Figure 1. Total volume stock of the Hungarian forests since 1981.

4.2.2. Project level

The estimation of carbon stock changes in the below ground biomass may not be necessary in projects, either on the ground that, if trees are planted in areas with no tree biomass, below ground biomass can only increase. Yet, more carbon can be credited in projects if the carbon stock changes in the below ground biomass are added to the carbon stock changes of other pools. Depending on the type of afforestation (plantation vs. afforestation with slow growing indigenous species), initial spacing (e.g. dense to attain crown closure as early as possible vs. sparse spacing that can be maintained until the final harvest), and thinnings (in addition to the previous factors, this may depend on actual market situations), the below ground biomass can develop faster or slower, but its build up can continue for long. It may be worth for project participants to try to get at least an underestimate of this build up, however, both growths and losses must also be accounted for when this option is taken.

In case of the test site in Hungary, afforestation was done with fast growing species like Black locust, Black pine and indigenous Poplars. With these species, the build up of below ground biomass is fast, and the under ground biomass can be substantial. This can easily be shown by the amount of trunks that are dug up or chopped in the region at the end of rotation period as a part of soil preparation for the next tree generation.

To get any estimate of the change of below ground biomass, two methods could be used. One is to use the same data as for the national GHG inventory, which are broad estimates using literature values, which were developed in case studies. The values can be found in Somogyi (2002). The other method is to actually measure the amount of coarse roots in consecutive field surveys. In Hungary, the spatial variation of the site conditions is high, however, soil is sandy and loose in most parts of the area available for afforestation, and also in most parts of the test site, and it may be feasible to take measurements at least at some representative places. Trunks extracted from soil at the end of harvest in neighbouring stands may also be used to get an estimate of belowground biomass.

4.3. Dead organic matter

4.3.1. National GHG inventory level

The dead organic matter is not currently monitored separately in the national GHG inventory. However, the amount is taken into account in the volume increment estimate and in the harvest statistics using the assumption that all carbon in the wood becomes dead and is emitted into the air in the inventory year. Some of the standing dead wood, which can still be used for some purposes like fuelwood, is harvested and included in the statistics on standing volumes. This is especially the case when higher than normal level of pests and pathogens forces the forestry companies to conduct sanitary cuttings.

Concerning the total current amount of dead organic matter in all the forests, the following expert judgement level considerations can be made. First, the age structure is characterized by predominantly young forests, due to the large afforestations in the past several decades, but the area of aging forests of indigenous species also increases due to the current increase of rotation age. Furthermore, silvicultural practice has shifted towards less frequent, but more intensive thinnings on the one hand, and abandoning or delaying thinnings in economically marginal forests on the other. Thinning practices also tend towards establishing mixed, less uneven aged stands. The overall consequence of all this most likely is that the amount of dead organic matter in the forests is slowly increasing, thus the dead organic pool is currently a sink rather than a source of emission. It seems likely that this tendency will last at least until the end of the first CP, therefore, it seems unnecessary to estimate and report the change of the amount of dead organic matter in Hungary at the country level.

4.3.2. Project level

In projects, dead trees appear sooner or later in most afforestations. For some years, only standing trees will appear, later, laying deadwood will be found, too. Since there are no data available in the literature on the amount of this dead wood, and since mortality is highly case specific, only local measurements can be used to assess the amount of dead wood.

Standing trees can often be accurately assessed as specially marked tally trees as long as their most important characteristics can be measured. For example, if volume is assessed to estimate biomass, breast height diameter and total tree height must be measurable, but if biomass is measured, the dead trees in the sample plots must be felled and weighted (for volume and biomass measurements, see section 4.1 on above ground biomass above). For lying trees, a separate monitoring method may be necessary because of the uneven distribution of lying trees across the project area.

However, in well managed plantations it can be considered a viable option that dead organic matter is not reported at all. At the beginning of the afforestation, dead organic matter may not exist at all, depending on former land use (e.g. cropland with basically all biomass removed in last production year, or if left biomass is regarded as part of the litter or soil pool). Later, the increase of the dead organic matter pool is always higher than the decrease from existing dead wood due to decay for decades. Thus, it can easily be shown that this pool is not a source for decades, and considering the costs to measure changes in this pools, project participants can decide not to report on this pool.

4.4. Litter

4.4.1. National GHG inventory level

The change in the amount of litter is currently not measured at the national level at all. Most probably, it will not be measured for years, either, for similar reasons that are described at the section on dead organic matter above.

4.4.2. Project level

The development of litter in afforested areas can be substantial, at least in the first few years of the afforestation. The leaf production saturates only one or several decades after the establishment of the stand. Also, the decay of leaves may take several years, and as long as the trees are young they mostly have living parts, leaves among others, the amount of which can be substantial even compared to the annual volume increment. Therefore, this pool can be a considerable sink in the young plantations.

Like for the deadwood pool, no measurements are available for the temporal development of the litter pool in Hungary, so field measurements are necessary to estimate changes in this pool.

4.5. Soil

Soil contains a lot of carbon, a possible source of emissions, but it is a possible sink of much carbon, too. Thus, it is highly important that this pool is assessed as accurately as possible both at the national and the project level on the carbon stock changes in soils. However, since soils are highly variable and difficult to investigate, it is usually very difficult to get data on soils. Moreover, changes are usually small or very small compared to the amount of carbon stored in the soil at any time.

4.5.1. National GHG inventory level

In Hungary, the amount of carbon is not estimated as a routine procedure in any soil analysis or monitoring system. Currently, most forest soils are analysed by the National Forest Service with the main objective to best select tree species for regeneration or afforestation of lands. The carbon content is not necessary for this species selection, and although standard laboratory measurements are available for many hundreds or thousands of soil profiles in many site and stand types, these measurements do not include carbon data. No work has been done so far to search for or derive data that could be used for the GHG inventory. Some efforts are under way to analyse the possible use of another soil monitoring (Soil Protection Information and Monitoring), under the management of the Central Service for Plant Protection and Soil Conservation (ONTSZ). Within this system, only humus content of soil is measured, too, but there are already some repetitions of the measurements, which may allow to develop useful data for the forest soil GHG monitoring.

4.5.2. Project level

At the project level, carbon stocks in soils can both increase and decrease. The increase is mostly due to root and litter production of trees, and much decrease may be due to soil preparation that exposes organic matter to oxygen, which speeds up decomposition. Because of the complexity of processes and situations, no theory can reliably predict the tendency on most sites, therefore, empirical data are required.

Several approaches are possible to get data in Hungary. The most direct one is to take soil samples in the various strata and analyse the chronosequence. This procedure most likely requires the collection and analysis of many soil samples, because the changes are small during a few years, not only in relation to the amount of carbon already stored in the soil, but also regarding the high spatial variability of the carbon content. In order that any changes in the carbon content of the soil can be detected, enough samples must be collected.

Another approach is to use research data from similar situations. No such research data are available at the moment, however, a study is under way within the Hungarian test site, in which carbon data are collected on representative sites in Black Locust stands, which may be one of the most important tree species to be used in afforestations in Hungary. In this study, samples from similar site are collected in stands of varying age. This way, false chronosequences are expected demonstrating the magnitude of carbon stock changes in such stands after afforestation.

A third possibility is to obtain data used in the national GHG inventory if any. A prerequisite of using such data is that the national inventory contains data for similar site conditions, and possibly for young stands. As this is not the case for the test site, direct measurements are necessary.

5. Information on the uncertainty of emission and removal estimates

It is well known that the uncertainty of emission and removal estimates is rather high in the LULUCF sector. According to the GPG (IPCC 2004), the net CO_2 emissions or removal uncertainties are within -50% to 100% (Table 5.4.6, chapter 5.4.7.1). It is of primary importance to decrease uncertainty especially where emissions are expected to be high, and also in projects, where the correct and fair estimation of net removals is in the interest of all project participants.

To get an overall estimate for the uncertainties of the net removals in Hungary, expert judgements were made for the national GHG inventory for the variables included in equation *(5)* above. The specific values are included in **Table 5**. A sensitivity analysis was also made to see how much effect of the change of the individual variables can have on the accuracy of the total net removal estimates. These data are also included in **Table 6.**

Table 5. Uncertainty estimates (based on expert judgement) of carbon stock changes in the AGB pool for the Hungarian forests in the national GHG inventory and in projects.

Variables in equation *(1)*	Estimated uncertainty
Volume growth	± 5%
Biomass conversion and expansion factors for living trees	± 5%
Volume of commercial harvest	-20% - +5%
Volume of fuelwood	-20% - +5%
Volume of "other wood removed"	-50% - +100%
Biomass expansion and conversion factors for harvested volume	± 10%
Carbon fraction of wood	N/A

Table 6. Sensitivity of the estimated net carbon removals in the national GHG inventory to changes in input data used for the estimation. The table values are deviations, in %, of removals estimates with decreased or increased values of input data (in %) from removal estimates that were calculated using original input data. CAInet

per CAI gross (net current annual volume increment per gross current annual volume increment) is the discount factor to derive net volume increment and is taken as 0.95 (see chapter 4.1.1.2).

Assumed deviation (%) in a single input data	Gross volume increment (m^3)	CAInet per CAIgross	BEF (t/m^3)	Commercial harvest (m^3)	Total traditional fuelwood consumed (m^3)	Total other wood use (m^3)	Carbon fraction
-20	-40,8	-40,8	-12,0	10,4	10,1	0,3	-20,0
-10	-20,3	-20,3	-5,5	5,2	5,1	0,1	-10,0
10	20,3	20,3	4,4	-5,2	-5,1	-0,1	10,0
20	40,8	40,8	7,8	-10,4	-10,1	-0,3	20,0

The effect of changing carbon fraction value is obvious, because it is a multiplying factor for the whole equation that is used to calculate total net removals. The effect of possible errors in other variables differs, with the highest effect having the increment values. Based on expert judgement, the increment can be higher than estimated due to effects of climate change and other environmental factors (based on Somogyi 2004), and harvests may also be underestimated, however, the accuracy of the increment estimates has a higher effect, so it can be inferred that removals are still underestimated for Hungary.

For projects, similar sensitivity analysis and even estimating the error budget is necessary, however, variance data and data on possible biases must be estimated based on the field survey data and other project specific information.

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