Potential CO_2 reductions by SRF via CDM/JI projects

Relates to tasks 4.1. and 4.2 ('business model')

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CO2EmissionReductionsBySRF *V 1.2*

Contents

Contents 1

1 Key messages 2

2 Carbon pools in A/R CDM forestry projects 5

3 Green house gas impacts of short rotation forestry (SRF) 8

Systematic description of the impact of short rotation forestry (SRF) on green house gas (GHG) emissions

3.1 Impacts from fuel replacement by using wood from short rotation forestry (SRF)) . . . 8
3.2 Green house gas emissions from the production of short rotation forestry (SRF) . . . 9
3.3 Green house gas effects of land-use-change by categories . . . 9
3.3.1 Direct land-use change (dLUC) . . . 10
3.3.2 Indirect land-use change (iLUC) . . . 14

4 Findings from literature 15
4.1 Calculated values for green house gas (GHG) emissions from short rotation forestry (SRF) for bioenergy production vary widely in literature and often do not account emissions caused by land use change. . . . 15
4.2 Emissions caused by land use change are of particular importance. Within this category emissions from indirect land-use change result very high. . . . 16
4.3 The energy reference system has big influence on potential green house gas (GHG) emissions reductions. . . . 18
4.4 Helpful documents from the UNFCCC . . . 19
4.4.1 CDM methodology booklet . . . 19
4.4.2 Methodologies . . . 19
4.4.3 Methodological CDM tools . . . 20
4.5 Helpful documents from the IPCC . . . 20
4.5.1 The IPCC guidelines . . . 21
4.5.2 Provided default values . . . 21
4.5.3 The IPCC emission factor database . . . 21

5 Tools to calculate green house gas (GHG) balances of Short Rotation Forestry 22

A small spreadsheet tool developed by energieautark consulting gmbh.

5.1 A spreadsheet tool developed within Benwood . . . 22
5.2 GEMIS - a large database . . . 25

6 A brief overview on A/R CDM projects submitted so far 26
6.2 A list of A/R CDM projects submitted so far . . . 29

7 Leakage as dealt with in A/R CDM projects submitted so far 35
7.1 Leakage as taken from some projects . . . 36
7.2 UNFCCC Tools for leakage . . . 38
7.3 Leakage as it may be treated in small scale A/R CDM projects according to the UNFCCC . . . 39

8 Green house gases from the usage of the wood **40**

9 Research requirements **41**
9.1 Eligibility of land 41
9.2 Determination of the baseline 42
9.3 Demonstration of additionality 42
9.4 Estimation of changes in carbon pools 42
9.5 Estimation of changes in above-ground biomass 43
9.6 Estimation of changes in below-ground biomass 43
9.7 Estimation of changes in dead wood 43
9.8 Estimation of changes in litter 43
9.9 Estimation of changes in soil organic carbon 44

10 A critical view on the CDM project scheme **44**

A Energy demand of human beings, animals and agricultural machinery, associated carbon emissions **45**

B Carbon pools to be monitored in large scale A/R CDM projects **46**

C Data on carbon content of some tree species in India **47**

D Pictures of tree root systems in northern India **48**

Glossary **49**

References **57**

1 Key messages

1. It is important to understand that there are largely different realities of short rotation forestry (SRF). The bandwidth is from large scale plantations of several thousands of hectares with a high degree of mechanization down to homegarden systems which are usually harvested and cultivated purely manually. It ranges from plantations established as shelterbelts against desertification in marginal areas such as in India or in China to plantations in most fertile regions such as the Italian Po plains.

   The variety of framing conditions and influencing factors makes it impossible to make strong and simple generic statements on the green house gas (GHG) impact of SRF at a global scale.

2. While there is good data on relevant parameters such the fuel usage of related agricultural/forestry machinery and according processes (ploughing, planting etc.) uncertainty on the overall GHG impact of SRF rises extremely fast if the full scale impact of SRF is looked at, in particular when including effects *outside the plantation area* ('leakage' or 'indirect effects').

3. The impact on emissions from land use change tends to be negative - CO_2 emissions from land use change tend to rise - if SRF is established on *grassland* which is neither degraded nor highly intensively managed (in particular not fertilized). This assertion is due to the assumption that the entire plantation area is ploughed before planting trees and is harvested with heavy machinery which operates on the field, both activities

compacting the soil. Ploughing the entire area before planting the trees is a practice of establishing SRF currently dominating in Non Annex I countries. Ploughing, in general, releases soil carbon from established grasslands via increased respiration and erosion and thereby an increased loss rate for soil organic carbon. In many Non Annex I countries however, ploughing is often not the dominating practice of establishing cultures but rather planting holes are dug. No indications on data for this latter scenario could be found so far.

On the other hand the impact tends to be positive - CO_2 emissions from land use change tend to decline (carbon is fixed on the area) - if SRF is established on former *cropland* or on degraded land. See also the next item.

4. SRF performs better than annual crops

   Environmental impacts of SRF in general (not only referring to GHGs), related to the plantation area, i. e. what regards direct emissions, tend to be less detrimental in terms of energy demand and related emissions than annual agricultural crops cultivated on the same area.

   The reason for this tendency is that annual crops need annual activities (soil preparation, planting, weeding, harvesting) whereas SRF requires only relevant activities in the first year (soil preparation, planting, weeding) and in the year of harvesting. Simplifying this even further one may say what regards CO_2 emissions: overall, forest fixes more carbon than annual crops. SRF being a hybrid between cropland (or grassland) and forest fixes more carbon than cropland.

   However, there is a wide variation of how to cultivate trees and how to cultivate annual crops. This is why exceptions to the above tendency can be constructed easily in particular in those situations where, what regards SRF, periods between harvesting are very short (e. g. such as two years in Italy), heavy machinery is intensively used for weeding and harvesting and where, on the other hand, the cultivation of annual crops would have relied on 'low input' practices (e. g. reduced or no tillage, high share of manual labour etc.)

5. What regards direct emissions different influence factors decide on the net GHG balance. Among those factors is the choice how to establish and manage SRF systems. There seems to be little overall longterm data which would allow for taking into account the multitude of different possible SRF practices. This in particular regards the impact of SRF systems with reduced soil opening[1], organic soil amendments such as the application of green fertilisers or terra preta and systems with very long life spans of the tree-root-system in plantations which are cultivated in coppicing mode.

6. 'Leakage' (carbon impacts outside the plantation area) is of major influence when establishing carbon balances for SRF. According to Fritsche and Wiegmann [2008], on the average even the main carbon impact of SRF systems is to be expected by changes of land use induced elsewhere such as

   (a) by food or fodder production on current *grasslands or forests* or

   (b) by *intensification* of agricultural management on existing cropland or by *resuming* agricultural activities on land formerly cultivated but currently set-aside.

[1] Actually, the A/R CDM methodology AR-AMS0001 applies only to project activities implemented on lands where $\leq$ 10% of the total surface project area is disturbed as result of soil preparation for planting.

This land is cultivated to compensate for the area 'lost' by the newly established plantation area of SRF. See also sec. 7, 'Leakage as dealt with in A/R CDM projects submitted so far', p. 35 and sec. 4.2, 'Emissions caused by land use change are of particular importance. Within this category emissions from indirect land-use change result very high', p. 16.

7. Given the high uncertainty on indirect effects (leakage), in a conservative approach SRF should be established primarily
   (a) on degraded land or
   (b) in agroforestry systems.

   What regards degraded land see the example from the Moldova (2) project. On such areas indirect effects are likely to be much less in volume because the probability that agricultural crops would have been grown on those areas is small and carbon pools of degraded lands are usually expected to stay low or would even have further declined in the absence of additional activities such as tree planting. Obviously it is then important by which criteria the degree of degradation is assessed, in other words who decides on the eligibility of the land because not all projects have high standards such as the Clean Development Mechanism (CDM).

8. For SRF practices as dominating in Annex I Countries in 2011 a comprehensive literature review has been published by the university of Wageningen (Djomo et al. [2011]) bearing on 26 studies on carbon balances of SRF. One of the conclusions was that main carbon impacts, what regards *direct* emissions along the production chain (not from land use change), result from *harvesting* and from the usage of *fertilisers*. This is noteworthy as it is in contrast with the fact that fertilization seems to be of little effect if applied to SRF.

9. A spreadsheet has been developed within the current project for roughly estimating the carbon impact of SRF systems as currently cultivated in Non Annex I countries. However, this sheet only reflects a narrow concept of SRF with regard to practices as currently established in Non Annex I countries and possible in the future to be (re)introduced also in Annex I Countries.

2 Carbon pools in A/R CDM forestry projects

In afforestation and reforestation (A/R) projects atmospheric carbon has to be fixed and fixation has to be measurable. Measurements and calculations take account of different carbon pools, these are basically five compartments: 1. above-ground biomass 2. below-ground biomass 3. soil organic carbon 4. litter (litter fall or forest floor) and 5. dead wood
These pools are described in the following.

① Above-ground biomass This carbon pool usually accounts for the bulk of stored carbon in A/R projects. Dead wood and litter (litter fall or forest floor) are not included in this carbon pool although both, dead wood and litter (litter fall or forest floor), to a large extent are physically also 'above the ground'. The mass is assessed what regards measurements of trees, via measuring the DBH and evtl. also the height of trees. From the DBH and evtl. also the height via allometric equations the volume and the mass of a tree may be assessed. According equations have been widely established by forest science. What regards the projection of the future development of carbon stocks growth tables for tree species are used.

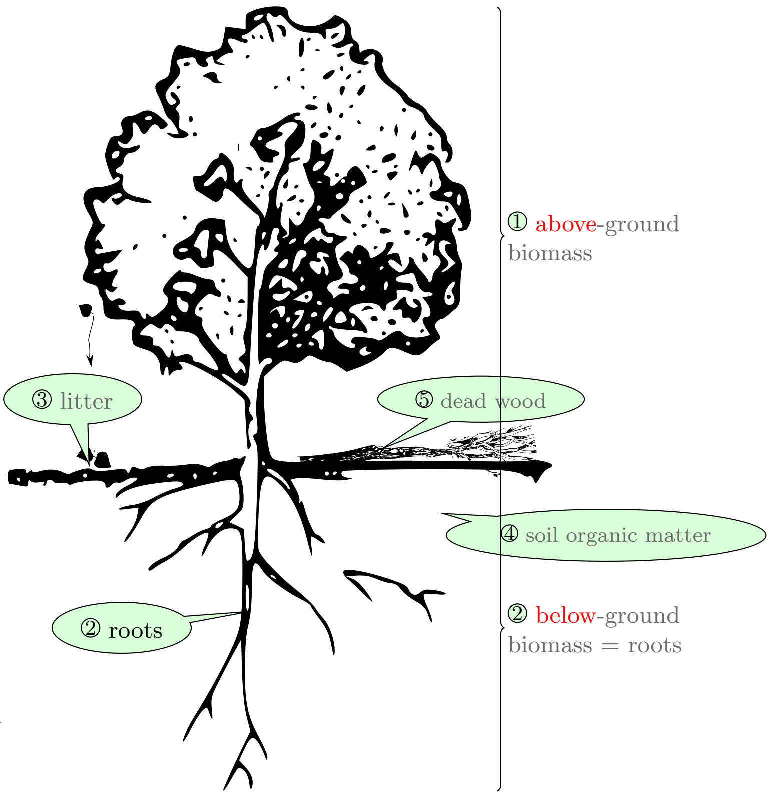

Fig. 2.1: Schematic of carbon pools influenced by trees. Tree schematic from Nair [1993].

② Below-ground biomass Below-ground biomass could be better denoted by 'coarse root system' in order to facilitate an immediate understanding. Misunderstandings should be avoided in the sense that the term includes only coarse parts of trees and other plants whereas soil organic matter is not part of the carbon pool 'below-ground biomass'. Please note that in SRF projects in coppicing mode the root increases during the lifespan of the tree (as with conventional forests) - see also ??, p. ?? - whereas the above-ground biomass is cut after each rotation and hence is reset to zero.

④ Soil organic carbon This encompasses all carbon in soil organic matter except for coarse matter (roots). Soil organic carbon is likely to change at a slow rate and to be an expensive carbon pool to measure (Pearson et al. [2005], p. 13). Soil organic matter is not considered in most of the registered A/R projects. One exception is a project in Moldova, described in UNFCCC (United Nations Framework Convention on Climate Change) [2008b], where soil organic carbon will be monitored between the years 10 and 20 years of the crediting period using sample plot measurements. Not taking into account soil organic carbon is often feasible in compliance with the CDM methodologies because usually the loss of soil organic matter is higher or the rate of increase is less in the absence of an A/R project than with the project. Please note that it is important that carbon which has reached the soil also remains fixed as long as possible, at least during the crediting period of the A/R project. Carbon may leach (see **Fig. 2.2**) or simply be oxidized and therefore be lost to the fixation. One technique to increase the duration of carbon in the soil is to convert biomass to biochar.

③ Litter (litter fall or forest floor) Litter (litter fall or forest floor) is not considered in most of the registered A/R projects as a carbon pool. For the reason see above the explanation on soil organic carbon. Also the team lead of the UNFCCC has stated during his speech on research needs (Galinski [2011]) in Barolo in 2011 on A/R CDM projects that he's not aware of any project case so far where litter fall would play a significant role.

⑤ Dead wood Dead wood is not considered in in most of the registered A/R projects as a carbon pool. For the reason see above the explanation on soil organic carbon.

Fig. 2.2: Soil of a heath in Germany. Organic matter (dark vertical strains) leaches and is thereby lost. Source: Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen [2007]

Harvested wood products Much of the wood that is harvested from Forest Land, Cropland and other types of land use remains in products for differing lengths of time. This chapter provides guidance on how to estimate and report the contribution of these harvested wood products (HWP) to annual AFOLU CO2 emissions/ removals. HWP includes all wood material (including bark) that leaves harvest sites. Slash and other material left at harvest sites should be regarded as dead organic matter in the associated land-use category in Chapters 4, 5, 6, 8 and 9 of the Guidelines and not as HWP. HWP

constitutes a carbon reservoir 2. The time carbon is held in products will vary depending on the product and its uses. For example, fuelwood and mill residue may be burned in the year of harvest; many types of paper are likely to have a use life in uses less than 5 years which may include recycling of paper; and sawnwood or panels used in buildings may be held for decades to over 100 years. Discarded HWP can be deposited in solid waste disposal sites (SWDS) where they may persist for long periods of time. Due to
An exponential decay is assumed. Inherited emissions (from 1900 onwards).
Table 12.2 on page 17. Formula on decay rate.

3 Green house gas impacts of short rotation forestry (SRF)

To reverse man-made climate change only by carbon sequestration via biomass is not possible. Even if all historic changes in land use which have been made until the year 2000 would be reversed by a global afforestation the concentration of CO2 in the atmosphere could be reduced only by 40 to 70 ppm. On the other hand the concentration of CO2 in the atmosphere today is already about hundred ppm above the preindustrial level (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WBGU) [2009], p. 123). Nevertheless SRF can contribute its according share in the overall reduction targets, The potential of SRF to reduce CO_2- resp. GHG[2] emissions (caused by energy conversion technologies) depends on several factors.
To obtain GHG balances for bioenergy in general and for SRF in special, we have to ask three main questions:

1. *Fuel replacement:* To what extent will the usage of SRF biomass replace 'conventional' energy (fuel) production[3] and how high are the GHG-emissions of this (potentially) substituted energy production?
2. *Emissions from plant cultivation* How high are GHG-emissions caused by the production of SRF biomass and the subsequent energy conversion processes?
3. *Emissions from land use change* How does land use change affect the GHG balance of SRF projects? (The overall effect of direct and indirect land use change on GHG emissions may be positive (reduced GHG emissions) or negative (increased GHG emissions).

These main questions can be divided in several subquestions / sub-aspects:

3.1 Impacts from fuel replacement by using wood from short rotation forestry (SRF))

Answering points 1a to 1c results in an estimation of the amount of energy produced by SRF biomass on a specific area for the different purposes of heat, electricity and/or transport fuels and thus the amount of substitutable energy production (in a certain region).

Potential output of short rotation forestry (SRF) biomass. This depends on the (average) *yield per hectare* of SRF biomass and the total amount of land that could be allocated for SRF production (in a certain region).

[2]The term GHG emissions includes emissions from all GHGs and is measured in CO_2-eq (CO_2 equivalent).
[3]resp. energy conversion

Allocation of short rotation forestry (SRF) biomass to certain usages of the wood. Relevant questions: Which share of the overall SRF biomass is allocated for energy production, which share for other usages (like paper production)?[4] And within the energy sector – what is allocated to heat, electricity or transport fuels?

Conversion efficiency. If one ton of harvested SRF biomass were converted to heat, electricity or a second generation transport fuel and if further converted to useful energy: How high would the respective output of (useful energy) per input unit of biomass be?

Green house gas (GHG)-emissions caused by the substituted energy conversion technologies. These substituted emissions from energy conversion technologies are often denominated as emissions of the 'reference system' or of the 'baseline'.

3.2 Green house gas emissions from the production of short rotation forestry (SRF)

These are direct GHG-emissions caused by production of SRF biomass (and the subsequent energy conversion processes). Depending on system boundaries two types of assessments for production-caused GHG emissions are differentiated (Djomo et al. [2011], p. 185):

cradle-to-farmgate assessment Includes the acquisition of raw materials, cultivation and harvesting, and sometimes transport and storage at the farm gate or at some intermediary storage place.

cradle-to-plant assessment Includes the transport of biomass to the power plant, biomass fuel preparation, conversion to electricity, and treatment of waste in addition to the stages listed in the cradle-to-farm gate assessment (this description is relevant for electricity production).

From the information how much and which type of energy has been used as well as from the information on the usage of fertilizers CO_2 emissions may be calculated. Fritsche and Wiegmann [2008], page 62, states that the data uncertainty on total energy requirement is low what regards emissions from production. It has to be added that Fritsche and Wiegmann [2008] states that improved (with regard to energy input and carbon impact) management practices such as zero tillage, fertilisation via sewage sludge have not been taken into account in the study.
However, this implies that for a GHG assessment the cultivation practices have to be sufficiently well described, in particular taking into account major differences between Annex I Countries and Non Annex I countries. In the following some of these relevant differences are provided:

3.3 Green house gas effects of land-use-change by categories

Two types of land-use change are differentiated, direct land-use change (dLUC) and indirect land-use change (iLUC) (WBGU 2009, 180ff.).

[4] Cascadic effects are not taken into account. If wood from SRF is used for timber the wood is not fully lost for energy purposes but the usage is just postponed - see also sec. 2, 'Harvested wood products'. Maybe decades later when a house is dismantled woody parts may be incinerated. By using it in the first place for non-fuel purposes, however, a later thermal usage may become more difficult due to contaminations which limit the thermal usage to specialized incineration plants which may deal with the contamination in terms of gaseous (flue gas) and solid (ash, slag) emissions.

3.3.1 Direct land-use change (dLUC)

Direct land use change takes into account that land dedicated to growing energy crops in a project was dedicated to another purpose before growing energy crops. The effect of direct land use change on GHG emissions may be positive (reduced GHG emissions) or negative (increased GHG emissions). In the first case carbon fixation happens, more carbon is stored in the biomass (above-ground and below ground biomass) and in the soil compared to the previous case whereas in the second case less carbon is stored and thus GHG emissions are increased.[5]

Fig. 3.1: If grassland is converted to short rotation forestry (SRF) including a ploughing step carbon emissions increase. The picture shows a savannah in Ethiopia. Photograph: http://www.lieden.net/articles/20080311-1.html

Fig. 3.2: The Qixing River Wetland in Heilongjiang Province was recently named a wetland of international importance at the Sixth Asian Wetland Symposium. Wetlands are important carbon storages and caution has to be applied when designing tree plantations (there is a separate methodology from the UNFCCC on this issue of tree plantings on wetlands). Photograph: http://en.radio86.com/chinese-media/restoring-wetlands. There specified as a source of the Photograph: 'Beijing Review/Hao Yuanzheng'.

[5] In the context of SRF in CDM A/R projects an example for the second case would be if due to (imaginary) repeated intensive tilling, harrowing and ploughing which comes along with an A/R project the soil would be opened that often that organic carbon in an originally carbon rich soil is lost to an extent that it more than offsets the carbon fixation which occurs in the planted trees.

There are noteworthy differences around the globe what regards cultivation practices of SRF and hence the direct emissions from land use change. Since these differences will likely have an impact on CO_2 emissions some differences are outlined in the following, however, without quantifying them.

Leaving roots in the soil versus uprooting trees In India cultivating trees in coppicing mode (distinguish SRF from short rotation coppice (SRC)) is often not practised whereas coppicing is frequently encountered in Non Annex I countries, especially where it is merely about cultivating wood for energetic usage. Trees can be kept alive during a longer time span on the field, e. g. for 20 years or more, while cutting the above-ground biomass back every two to five years. While the above-ground biomass is harvested and regrows via coppicing the root system continuously develops and establishes a carbon stock in the soil.

Fig. 3.3:

Fig. 3.4:

A decisive choice is how this carbon stock established by the roots is dealt with: Whereas in Europe at the time when trees are to be completely removed in order to clean the soil for another crop which is planted instead of the trees - often these are annual crops - roots are destroyed and left in the soil.

Fig. 3.5: Forest mill used in Austria destroying roots of the trees from a short rotation forestry plantation where annual crops shall be planted.Photograph: Lewis.

In India trees are often uprooted, i. e. digging out the roots. The choice of root destruction/removal influences the medium to long term carbon stock balance in the soil.
However in conventional forestry within Annex I Countries it is known that in Scandinavia trees are also removed completely in the sense that also the roots are removed.

Removing leaves from the plantation site for fodder It is an ancient technique applied worldwide to use leaves as fodder or as bedding material for animals. See the according article on the usefulness of leaves from various trees in . Leaves contribute

considerably to litter fall and thereby to building up organic matter in the soil. If they are removed this can make a difference in soil organic carbon stock.
In Albania (12) it is indicated that material from the coppices will be used as fodder.

Time span between two harvests The time span between two harvests has an impact on carbon emissions for two reasons, in particular if harvesting is done with large self-propelling agricultural or forestry machinery.

1. nitrogen emissions from soil may increase if soil is compacted because the probability for anaerobic conditions and hence denitrification rise.
2. Harvesting in Annex I Countries causes the bulk of CO_2 emissions in the total project cycle (Djomo et al. [2011]), accordingly the time span between two harvests is important. In Europe this span currently ranges between about two and five years for the large industrial cultivations. In India the range is between four and eight years.

Accordingly the time span is more important in Annex I Countries than in Non Annex I countries where more manual harvesting is done and potentially also with less soil compaction.

Producing logs versus producing wood chips Dubas, Italy
Haryana

Agroforestry, home gardens and 'trees outside forests' (TOF) versus closed short rotation forestry (SRF) stands

Fig. 3.6: Eucalyptus alley along a road in northern India, state of Haryana. Photograph: Thomas Lewis (energieautark consulting gmbh).

To calculate GHG balances from direct land use change default values may be used (Gnansounou et al. [2008]). The following table **Tab. 3.1** shows standard values for different types of land use change related to a time span of 20 years. Depending on specific (agricultural) practices there may be significant deviations from these standard values. With regard to SRF the table shows that in the case of poplar in an SRF plantation carbon fixation happens when the previous land use was cropland but in case the previous land use was grassland more carbon is released and thus GHG emissions increase. An extraordinary negative effect (regarding GHG emissions) happens when tropical rainforests are reduced for oil palm plantations. In contrast to indirect land use (see below) the spatial system boundary for direct land use change coincides with the area where the new (energy) crops are planted.

Fritsche and Wiegmann [2008] in his study has analysed as systems which are typically displaced 'grassland' and 'cropland'. Some of the results are diplayed in **Tab. 3.1**.

	1	2	3
	new energy crop	**previous land use**	**additional GHG emissions (kg CO_2/ha/a) induced by the new crop**
1	wheat	grassland	2,630
2		cropland	0
3	maize	grassland	2,630
4		cropland	0
5	poplar (SRF)	grassland	1,255
6		cropland	-1,375
7	sugar cane	savanna	14,428
8		degraded land	-3,722
9		cropland	-055
10	rapeseed	grassland	2,630
11		cropland	0
12	oil palm	trop. rainforest	28,417
13		degraded land	-13,750
14	jatropha	cropland	-0,458
15		degraded land	-4,125

CO2AgricultureForestryEmissionTables.*areaSpecificCO2EmissionChangesDueToNewCrops*

Tab. 3.1: Impact on GHG emissions by new crops what regards direct land use change (emission changes only on the plantation area taken into account). Source: Fritsche and Wiegmann [2008], p. 19. The values are based on IPCC (2006). Negative values mean carbon fixation, positive values additional carbon emissions by the new crop.

The according input data for the above results are not directly published in the according report but reference is made to the GEMIS database (Fritsche and Wiegmann [2008], page 17). Beyond this statement there is no further specification on the assumed cultivation practices nor a breakdown of emission data what regards the contributions of different processes such as fertilization, harvesting etc.

Above values are specified in units of kg per hectare and *year*. However, enrichment and in particular depletion of the soil with carbon is bound to physical limits. What regards depletion not more carbon can be lost than either preexisting in the soil or lost in terms of untapped future potentials for further carbon enrichment of the soil. The above values are to be understood averaged over a time period of twenty years.

3.3.2 Indirect land-use change (iLUC)

Indirect land-use change considers changes in land use that are caused by new energy crop plantations but emissions do not happen at the site where the new energy crops are planted. For instance, if a SRF plantation is planted on cropland and food demand does not decrease then replaced food crops have to be planted somewhere else. The overall effect on GHG emissions is especially problematic if new areas with a high amount of stored carbon (like forests or wetlands, see **Fig. 3.2**) are accessed for growing food crops. Indirect land-use change by definition also happens when the same crops continue to be planted but the *usage* of these crops changes (e.g. wheat formerly used as food crop and then used as energy crop).
After all, indirect effects are the consequence of system boundaries set too tightly. If system boundaries were made wide enough, by definition there would be no more indirect effects. (Fritsche and Wiegmann [2008], Page 12.)

Fig. 3.7: Farmers during field work in Burkina Faso. Displacing food crops by short rotation forestry (SRF) may lead to other areas getting deforested in order to compensate for the land lost for food production due to the short rotation forestry (SRF) plantation. Photograph: http://www.abcburkina.net/.

The effects of indirect land-use change on GHG balances are estimated to be highly significant according to Fritsche and Wiegmann [2008] (see section 4, 'Findings from literature'). Actually, they are likely to be responsible in many cases for the bulk of CO_2 emissions. Accordingly, further research efforts on improving the accuracy of assessing the carbon impacts within the system boundaries of the plantation area are of limited practical relevance with the regard to the goal of assessing the overall carbon impact of SRF systems.

Fritsche and Wiegmann [2008], page 62, states (translated from German) that GHG emissions due to indirect land-use change may differ by +- 50%. and that 'even further and deeper analysis on land use change (and N_2O emissions) would not reduce the current uncertainty. Such activities could only achieve a broader description of possible scenarios

but would hardly reduce the existent uncertainty on data narrowing the bandwidth of data already available.'
An overview on different methods to assess the iLUC effects on GHG (balances can be found in IFEU (Institute for Energy and Environmental Research) [2009]).
Fritsche and Wiegmann [2008] use an *iLUC factor* to assess GHG emissions due to indirect land-use change. The factor is derived from considering globally traded agricultural products (maize, wheat, rape seed, soya, oil palms) which could be replaced from growing energy crops[6].

There is still a debate going on about which method (and which reference values) to use for incorporating indirect land-use change into the calculation of GHG balances. Searchinger [2010] proposes to use multiple methods to provide a reasonable range for final estimates[7] and points out that not including iLUC would be a 'critical climate accounting error' (Searchinger et al. [2009]).

4 Findings from literature

The CO_2/GHG reduction potential of SRF has already been the topic of numerous scientific papers and assessments. In the following important findings based on a literature review are presented.

4.1 Calculated values for green house gas (GHG) emissions from short rotation forestry (SRF) for bioenergy production vary widely in literature and often do not account emissions caused by land use change.

A recently published paper, Djomo et al. [2011], reviewed 26 studies on energy and GHG balances of bioenergy production from poplar and willow published between 1990 and 2009. The reviewed studies differ in various aspects: methodology (energy analysis, life-cycle analysis), impacts studied (CO_2-emissions, GHG-emissions, other impacts), system boundaries, conversion technology (co-combustion, combustion, gasification), reference system (coal power, grid electricity, other), short rotation species (poplar and/or willow). Regarding system boundaries two types of studies are distinguished - cradle-to-farm gate and cradle-to-plant assessments. Most of the cradle-to-farm gate assessments include the acquisition of raw materials, cultivation and harvesting, and sometimes transport and storage at the farm gate or intermediary storage place. The cradle-to-plant studies include the transport of biomass to the power plant, biomass fuel preparation, conversion to electricity, and treatment of waste in addition to the stages listed in the cradle-to-farm gate studies (Djomo et al. [2011], p. 185). Sixteen studies made the cradle-to-plant assessment and the rest (ten studies) were cradle-to-farm gate assessments. As ten of the cradle-to-plant assessments also presented the results of the cradle-to-farm gate stages

[6] By considering trading shares and plant yields for the most imported producer countries (EU, USA. Brasil, Indonesia) a global mix of land is calculated that needs to be accessed to produce the replaced food crops. It is assumed that the areas which need to be accessed additionally for food production are grassland in the USA and EU, in Brasil savannahs and in Indonesia tropical rain forests. An iLUC factor of 50% means that not the complete calculated area has to accessed but just 50% of it due to yield increases on already agriculturally used areas and the activation of unused areas.

[7] 'Just as it would be a mistake to base climate policy on any one climate model, so it is a mistake to estimate ILUC from any one land use model. [...] By comparing these intermediate estimates of different models, and analyzing their empirical basis, a reasonable range of final estimates is feasible.' (Searchinger [2010], 9)

20 cradle-to-farm gate studies could be extracted. Only two studies addressed effects of (direct) land use change, no study addressed indirect land-use change.
The data published in the reviewed literature gave energy ratios (ER, the ratio of energy output to energy input) between 13 and 79 for the cradle-to-farm gate and between 3 and 16 for cradle-to-plant assessments, whereas the intensity of GHG emissions ranged from 0.6 to 10.6 g CO_2-eq /$MJ_{biomass}$ for the cradle-to-farm gate and 39 to 132 g CO_2-eq /kWh electricity for the crade-to-plant assessments (for comparison: GHG emissions from coal: 96.8 g CO_2-eq per MJ_{coal}.)
Within the processes included in the cradle-to-farm gate studies harvesting and fertilization (i.e., fertilizer production plus their application) accounted for the majority of the energy inputs. The amount and types of fertilizer used, harvesting method, and assumptions about the yield per hectare were the main sources of diverging results for energy balance among the reviewed studies.
The wide range of cradle-to-farm gate CO_2 and GHG emissions observed among the reviewed studies can be mainly attributed to assumptions regarding agrochemical input (mainly fertilizer), N_2O linked to fertilizer input and the carbon sequestration process (soil carbon and carbon pools below ground). Many reviewed studies overlooked N_2O emissions from fertilizer application; those that included N_2O used the IPCC methodology for direct and indirect N_2O emissions estimation (IPCC (Intergovernmental Panel on Climate Change) [1996]). Few reviewed studies included the carbon sequestration process (soil carbon and carbon pools belowground) in their analyses. The paper points out that the sequestration of carbon in soil is site-specific and depends on factors such as existing soil carbon levels, climate, soil characteristics, and management practices.
To help to reduce the substantial variability in results, this review suggests a standardization of the assumptions about methodological issues. Likewise, the development of a widely accepted framework toward a reliable analysis of energy in bioenergy production systems is most needed.

4.2 Emissions caused by land use change are of particular importance. Within this category emissions from indirect land-use change result very high.

The concepts of direct and indirect land-use change were already explained in sec. 3.
Fig. 4.1 and **Tab. 4.1** show overall carbon emissions (resp. carbon fixation) for different bioenergy crops caused by direct and indirect land use change. Emissions are related to the gross energy content of the harvested biomass (t CO_2/TJ) and are averaged over a time span of 20 years. Also the emission level of fossil fuels is shown.
GHG emissions caused by land use change from growing certain energy crops may be in the range of or even higher than those of fossil fuels (**Fig. 4.1**). This is also the case for poplar harvested from SRF plantations if the previous land use was cropland or grassland. **Fig. 4.1** also shows that in cases where the previous land use was cropland or grassland the effects of indirect land-use change by far outweigh those of direct land use change (although carbon is fixed when SRF wood is grown on land used previously as cropland; emissions due to indirect land-use change lead to rather high net GHG emissions).
The best GHG balance results for growing perennial plants on degraded land because then net carbon fixation happens and the probability of the displacement of the cultivation food crops is low (although in some cases pastoral economies may be forced to move somewhere else which can be problematic if land with high amount of fixed carbon would be converted to pastures.)

Within the context of CDM projects effects from indirect land-use change are referred to as 'leakage', see also sec. 7, 'Leakage as dealt with in A/R CDM projects submitted so far', p. 35.

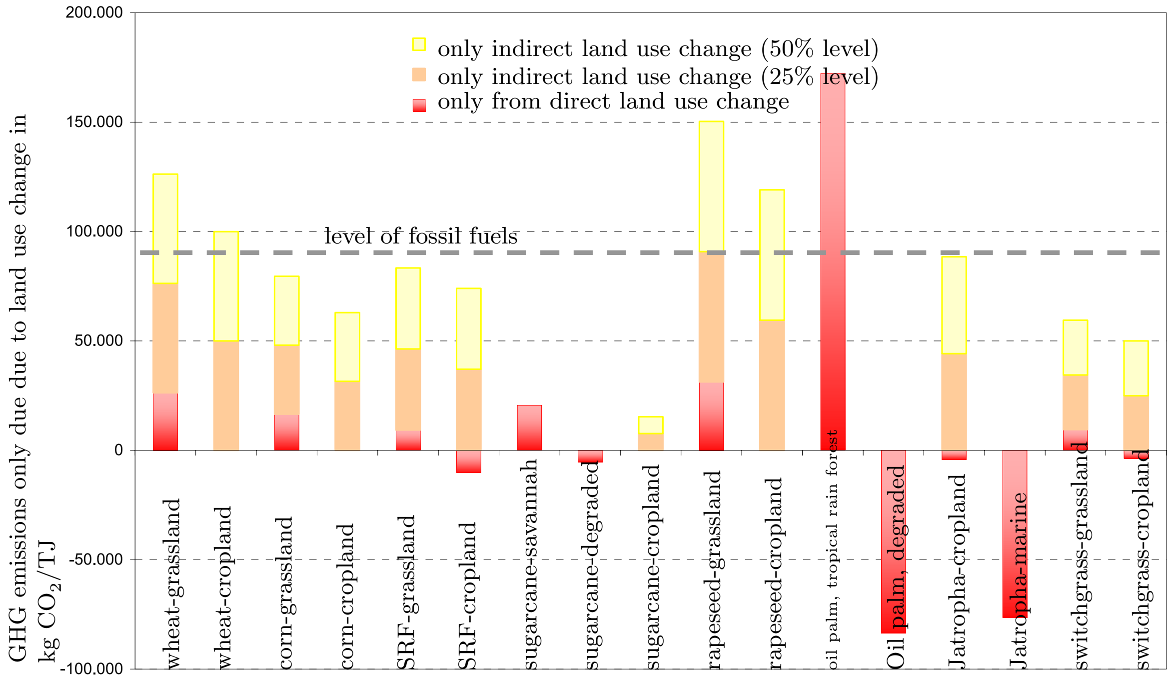

Fig. 4.1: GHG-emissions (related to energy content of bioenergy crop) resulting from direct and indirect land-use change for different bioenergy crops and land use (before conversion). Source: Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (WBGU) [2009], p. 183 resp. Fritsche and Wiegmann [2008].

All bars above the x-axis (positive values) of **Fig. 4.1** indicate a negative carbon impact of an according project (the substitution of the previous crop leads to an increase in emissions.) 'SRF-grassland' in the x-axis ticks means SRF substitutes the previous land-use which is grassland. This particular substitution leads to an increase in carbon emissions. In general, the analysis showed that most serious (negative) carbon impacts are observed if tropical rainforest or savannah is converted.

	1	2	3	4	5	6	7
	new energy crop	**previous land use**	**dLUC only**	**ILUC (25%)**	**ILUC (50%)**	**Sum LUC (25%)**	**Sum LUC (50%)**
1	wheat	grassland	16,572	31,506	63,012	48,078	79,584
2		cropland	0	31,506	63,012	31,506	63,012
3	maize	grassland	9,296	37,037	74,074	46,333	83,370
4		cropland	-10,185	37,037	74,074	26,852	63,889
5	poplar (SRF)	savanna	20,612	0	0	20,612	20,612
6		degraded land	-5,317	0	0	-5,317	-5,317
7	sugar cane	cropland	-085	7,692	15,384	7,607	15,299
8		grassland	31,309	59,524	119,048	90,833	150,357
9		cropland	0	59,524	119,048	59,524	119,048
10	rapeseed	trop. rainforest	172,222	0	0	172,222	172,222
11		cropland	0	0	0	0	0

CO2AgricultureForestryEmissionTables.*GHGBalancesForDirectdLucAndIndirectLandUseChangeiLuc*

Tab. 4.1: GHG balances for direct (dLUC) and indirect land-use change (iLUC). Source: Fritsche and Wiegmann [2008], p. 20. Negative values mean carbon fixation, positive values carbon emissions. All values in kg CO_2/TJ.

4.3 The energy reference system has big influence on potential green house gas (GHG) emissions reductions.

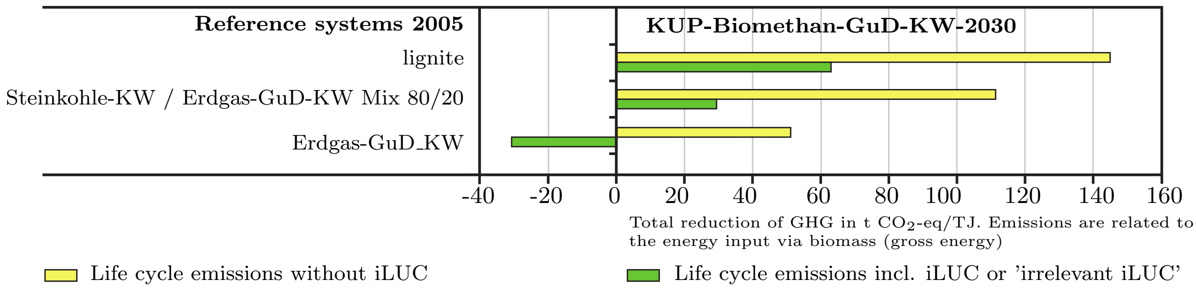

Fig. 4.2: Comparison of GHG emissions for emissions from electricity production from short rotation forestry (SRF) poplar with three reference systems for electricity production. Positive values (bars extending to the right) indicate emissions reductions, negative values (bars extending to the left) emissions increases compared with the reference system. Yellow bars: without iLUC (indirect land-use change), green bars: with iLUC. Source: WBGU (2008), p. 192

There are two significantly different cases for reference systems (electricity production from a coal-fired power plant, electricity production from a low fuel gas turbine) presented in **Fig. 4.2**, and one reference system is between those regarding GHG emissions. The biomass system considered is electricity production from gasified biomass coming from SRF. GHG emission reductions are much higher in case of the 'dirty' reference system (coal-fired power plant) compared with the case where the 'cleaner' reference system of the low fuel gas turbine power plant is assumed. One interesting detail in **Fig. 4.2** is that a biomass-based electricity production technology can be worse than a fossil fuel based system (reg. GHG emissions) when indirect land-use change effects are taken into account. If indirect land-use change is not taken into account in all cases reductions of GHG emissions happen (yellow bars) whereas the low fuel gas turbine (powered with natural gas) emits less GHGs compared with the biomass system if indirect land-use change is taken into consideration (green bars).

4.4 Helpful documents from the UNFCCC

4.4.1 CDM methodology booklet

UNFCCC [2010] The booklet (which should be rather considered a book in view of its volume) provides an overview on methodologies within the various CDM sectors. A considerable part of the book is dedicated only to methodologies within the A/R sector.

4.4.2 Methodologies

(Annotation: In Tab. 4.2 and Tab. 4.3 the actual titles of the methodologies have been abbreviated in order to increase readability.)

	1	2
	Acronym	**Small scale A/R CDM ...**
1	AR-AMS0001	... on *grasslands or croplands with limited displacement* of pre-project activities
2	AR-AMS0002	... on *settlements*
3	AR-AMS0003	... on *wetlands*
4	AR-AMS0004	... for *agroforestry - afforestation* and *reforestation* project activities
5	AR-AMS0005	... on lands having *low inherent potential to support living biomass*
6	AR-AMS0006	... for *silvopastoral - afforestation* and reforestation project activities
7	AR-AMS0007	... on lands having *low inherent potential to support living biomass*

CO2AgricultureForestryEmissionTables.*SmallScaleUNFCCCMethodologies*

Tab. 4.2: List of Small Scale UNFCCC Methodologies for A/R CDM project activities as per 06.01.2012. Source: http://cdm.unfccc.int/methodologies/SSCAR/approved

Moreover, there are as well 11 methodologies for large scale A/R CDM projects. Among those is also a methodology dedicated only to mangrove habitats:

	1	2
	Acronym	**Large scale A/R CDM ...**
1	AR-ACM0001	... of *degraded land*
2	AR-ACM0002	... of degraded land *without displacement of pre-project activities*
3	AR-AM0002	*Restoration of degraded lands* through afforestation/reforestation
4	AR-AM0004	... of land *currently under agricultural use*
5	AR-AM0005	... *for industrial and/or commercial uses*
6	AR-AM0006	... with *Trees Supported by Shrubs on Degraded Land*
7	AR-AM0007	... of Land *Currently Under Agricultural or Pastoral Use*
8	AR-AM0009	... on *degraded land allowing for silvopastoral activities*
9	AR-AM0010	... *on unmanaged grassland in reserve/protected areas*
10	AR-AM0011	... of land subject to *polyculture farming*
11	AR-AM0012	... of *degraded or abandoned agricultural lands*
12	AR-AM0013	... of lands *other than wetlands*
13	AR-AM0014	... *for industrial and/or commercial uses*

CO2AgricultureForestryEmissionTables.*largeScaleUNFCCCMethodologies*

Tab. 4.3: List of Large Scale UNFCCC Methodologies for A/R CDM project activities as per 06.01.2012. Source: http://cdm.unfccc.int/methodologies/ARmethodologies/approved.

From the UNFCCC (United Nations Framework Convention on Climate Change) [2009]:

Project participants may propose a new baseline methodology established in a transparent and conservative manner. In developing a new baseline methodology, the first step is to identify the most appropriate approach for the project activity and then an applicable methodology. Project participants shall submit a proposal for a new methodology to a designated operational entity by forwarding a completed “Proposed New Methodology: Baseline (CDM-NMB)” along with a completed “Proposed New Methodology: Monitoring (CDM-NMM)” and the Project Design Document (CDM-PDD) with sections A to E, including relevant annexes, completed in order to demonstrate the application of the proposed new methodology to a proposed project activity.

4.4.3 Methodological CDM tools

There are methodological CDM tools specifically designed for A/R CDM project activities and as well published on the UNFCCC website. They are listed here:

1. Combined tool to *identify the baseline scenario* and *demonstrate additionality* in A/R CDM project activities (not applicable to small scale projects)
2. Tool for the *demonstration and assessment of additionality* in A/R CDM project activities. (not applicable to small scale projects)
3. Calculation of the number of *sample plots for measurements* within A/R CDM project activities
4. Tool for *testing significance* of GHG emissions in A/R CDM project activities
5. Procedure to determine when *accounting of the soil organic carbon pool* may be conservatively neglected in A/R CDM project activities
6. Procedure to determine when accounting of the *soil organic carbon pool* may be conservatively neglected in A/R CDM project activities
7. Tool for estimation of GHG emissions from *clearing, burning and decay of existing vegetation* due to implementation of a A/R CDM project activity
8. Tool for estimation of GHG *emissions related to displacement of grazing activities* in A/R CDM project activity
9. Tool for estimation of carbon stocks, removals and emissions for the *dead organic matter* pools due to implementation of a A/R CDM project activity
10. Tool for the *identification of degraded or degrading lands* for consideration in implementing A/R CDM project activities
11. Estimation of carbon stocks and change in *carbon stocks of trees and shrubs* in A/R CDM project activities
12. Estimation of the increase in GHG emissions attributable to displacement of *pre-project agricultural activities* in an A/R CDM project activity
13. Tool for estimation of change in *soil organic carbon stocks* due to the implementation of A/R CDM project activities

4.5 Helpful documents from the IPCC

There is a strong interrelation between IPCC and UNFCCC documents in the sense that CDM methodologies reference data from publications of the Intergovernmental Panel on Climate Change (IPCC). Mostly this regards default values such as growth data, carbon stocks in soil etc. Data is included as tables and/or formulas in the IPCC publications.

4.5.1 The IPCC guidelines

The primary purpose of the IPCC guidelines was to support and harmonize the establishment of the *national CO_2 inventories* which are required from Annex I Countries within the framework of the Kyoto Protocol. The inventories are used for reporting to the United Nations Framework Convention on Climate Change (UNFCCC).
Distinct from this purpose of establishing inventories at a national scale is the development of CO_2 projects such as of A/R CDM projects. Such project development occurs at a much finer grained level than national inventories. Accordingly, additional methodologies tailored for the purpose of project development have been provided by the UNFCCC. In particular, these are CDM methodologies as described in sec. 4.4.2.

4.5.2 Provided default values

In order to provide an impression which kind of default values are provided by the IPCC some of the most relevant tables are included here. Please note that values are always 'conservative' which means that in A/R CDM projects the carbon impact in terms of greenhouse gas emission reductions is always rather underestimated then overestimated if using these values. The project developer will have to come up with more specific data if she/he wants to show that greenhouse gas emission reductions from her/his project are higher than those based on the IPCC default values.

4.5.3 The IPCC emission factor database

The IPCC database, called 'EFDB' (Emission Factor Database) for emission factors at
http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_main.php
From the website:

> The EFDB is meant to be a recognised library, where users can find emission factors and other parameters with background documentation or technical references that can be used for estimating greenhouse gas emissions and removals.

Search filters can be applied at different stages when using the database. There is a fulltext search available with interesting search facilities (key words and boolean operators) and one may also enter the database via the various carbon relevant categories such as 'land use change', 'agriculture', 'energy' etc. The database also includes data which is also included in Penman et al. [2003] in a more comprehensive form.

Examples for search results:

1. Looking for data for activities where *land is converted to forest land* one obtains 92 data records.
2. Searching for *'poplar'* results in three data records, however, there are 52 eight entries under the search word *'populus'* (botanical specification).
3. Entering *'willow'* results in one record only and there is only another data record for the search word 'salix'.

As stated above, not only carbon emission factors are specified but also other useful parameters for instance the basic wood density. For all data records data providers are asked to provide - besides the value of the parameter in question - also information on the region or on the regional conditions where the data was obtained from, the source of the data etc. Moreover insight into more details of each dataset - if available - can be obtained by clicking on an according button.

5 Tools to calculate green house gas (GHG) balances of Short Rotation Forestry

5.1 A spreadsheet tool developed within Benwood

Within the Benwood project and therein within T 2.2, “SRF/CDM reduction potential via computer simulation■ a spreadsheet tool for the CO_2 assessment was developed by energieautark. The tool is oriented on the methodological questions/steps outlined in section 1.

The tool allows a quick assessment with few inputs from the user of GHG balances for SRF in a certain region. (Input parameters have a yellow background colour within the spreadsheet's tables.)

For a more detailed approach on a project basis there are sophisticated software models available, for free or at a commercial basis, which allow for modelling tree growth, carbon fixation or release of soil organic carbon etc. One of these models is CO2FIX which has been used in the Moldova (2) project.

Different scenarios for biomass usage (1b) and previous land use (3c) may be specified.

The various (input) parameters are explained in sec. 1. The arrangement of subparts of the spreadsheet calculation is consistent with sec. 1 (meaning that e.g. 1a (Potential output of SRF biomass) adresses the same topic as in sec. 1).

Input data for the tool may be gained from various sources (literature, other tools such as GEMIS (see below), tools from the UNFCCC (like 'Tool to calculate the emission factor for an electricity system', UNFCCC/CCNUCC [2011]), own assumptions). It is the user's task to select meaningful input data.

The following example is an application of this tool to Austria. Regarding input parameters (for 1d, 2, 3a, 3b) sources with good data quality were chosen. The scenarios for biomass usage (1b) and previous land use (3c) were not chosen with the aim to be as realistic as possible but to show some variations in scenario assumptions. The results are presented per hectar, and for the total SRF area to be hypothetically allocated (in this case 20.000 ha).

With regard to GHG balances positive values mean GHG emissions whereas negative values mean reductions of GHG emissions.

The GHG balance shows that substituted energy and indirect land use are the most important parts of the GHG balances in a quantitative respect.

Country/Region	Austria

1. Replacement of „conventional/fossil“ energy production, GHG emissions of the reference system

1a. Potential output of SRF biomass

Average yield per hectar	8	t dry mass / ha
Energy content of SRF biomass	5	kWh/kg dry mass
land area to be allocated for SRF	20,000	ha

Explanation of background colours

yellow	input parameter
light yellow	default value that may be changed
cyan	data from reliable sources
light blue	derived data
green	Result

1b. Allocation of SRF biomass to certain usages.

	Scenario 1	Scenario 2	Scenario 3
Non-energy usage	20%	0%	30%
Electricity (only)	20%	20%	10%
Heat (only)	20%	20%	10%
Combined Heat&Elec.	40%	60%	50%

1c. Conversion efficiency

final energy in relation to energy content of biomass

	electricity	heat
Electricity (only)	0.45	
Heat (only)		0.95
Combined Heat&Elec.	0.35	0.65

1d. GHG-emissions of current energy mix

electricity	239.4	g CO2eq/kWh final energy	Data source	Innovative Energietechn. in Öst., Marktentw. 2009, S. 27/28
heat	323	g CO2eq/kWh final energy	Data source	Innovative Energietechn. in Öst., Marktentw. 2009, S. 27/28

2. Production of SRF biomass (and subsequent energy conversion processes)

Cradle-to-farmgate assessment

GHG emissions	4.2	g CO2eq/MJ	Data source	Djomo et al. 2011, mean value

Cradle-to-plant assessment

Electricity (only)	46	g CO2eq/kWh	Data source	Djomo et al. 2011
Heat (only)	19.66	g CO2eq/kWh	Data source	Djomo et al. 2011, cradle-to-farmgate + 30%
Combined Heat&Elec.	132	g CO2eq/kWh el.	Data source	Djomo et al. 2011

3. Land use change

3a. Direct land use change (dLUC)

prior use	GHG emissions (kg CO2eq/ha.a)	data source
cropland	-1375	Fritsche/Wiegmann 2008 resp. WBGU 2008
grassland	1255	Fritsche/Wiegmann 2008 resp. WBGU 2008
degraded land	-5000	own assumption

3b. Indirect land use change (iLUC)

prior use	GHG emissions		data source	per TJ gross energy content of biomass
cropland	74	t CO2eq/TJ	Fritsche/Wiegmann 2008 resp. WBGU 2008	
grassland	74	t CO2eq/TJ	Fritsche/Wiegmann 2008 resp. WBGU 2008	
degraded land	0	own assumption		
cropland	10.32	t CO2eq/ha.a		
grassland	10.32	t CO2eq/ha.a		
degraded land	0	own assumption		

3c. Land use scenario

Previous use of land where SRF is planted (rel. shares):

cropland	60%
grassland	30%
degraded land	10%

Results

Produced energy per hectar

	Scenario 1		Scenario 2		Scenario 3	
electricity	9200	kWh	12000	kWh	8800	kWh
electricity only	3600	kWh	3600	kWh	1800	kWh
electricity comb. h&p	5600	kWh	8400	kWh	7000	kWh
heat	18000	kWh	23200	kWh	16800	kWh
heat only	7600	kWh	7600	kWh	3800	kWh
heat comb. h&p	10400	kWh	15600	kWh	13000	kWh

total

	Scenario 1		Scenario 2		Scenario 3	
electricity	184	GWh	240	GWh	176	GWh
heat	360	GWh	464	GWh	336	GWh

GHG Balances *per hectar*	*negative values mean GHG emissions reduction*					
	Scenario 1		Scenario 2		Scenario 3	
Substituted energy	-8.02	t CO2eq/ha	-10.37	t CO2eq/ha	-7.53	t CO2eq/ha
Production and conversion of SRF biomass	1.05	t CO2eq/ha	1.42	t CO2eq/ha	1.08	t CO2eq/ha
Direct land use change	-0.95	t CO2eq/ha	-0.95	t CO2eq/ha	-0.95	t CO2eq/ha
Indirect land use change	9.29	t CO2eq/ha	9.29	t CO2eq/ha	9.29	t CO2eq/ha
Balance	1.38	t CO2/ha	-0.6	t CO2eq/ha	1.89	t CO2eq/ha

total						
	Scenario 1		Scenario 2		Scenario 3	
Substituted energy	-0.16	Mt CO2eq	-0.21	Mt CO2eq	-0.15	Mt CO2eq
Production and conversion of SRF biomass	0.02	Mt CO2eq	0.03	Mt CO2eq	0.02	Mt CO2eq
Direct land use change	-0.02	Mt CO2eq	-0.02	Mt CO2eq	-0.02	Mt CO2eq
Indirect land use change	0.19	Mt CO2eq	0.19	Mt CO2eq	0.19	Mt CO2eq
Balance	0.03	Mt CO2eq	-0.01	Mt CO2eq	0.04	Mt CO2eq

Tab. 5.1: Screenshots of tables from the spreadsheet developed within the Benwood project.

5.2 GEMIS - a large database

The GEMIS tool is a comprehensive database and analysis tool to model life-cycle emissions (and other parameters) for processes, especially within the energy sector (energy carriers, electricity, heat, transport, production processes). GEMIS 4.7 (the current version at the time of establishing this paper) contains 8973 processes, wood from SRF is part of 166 processes. Processes dealing with SRF reach from the cultivation of SRF biomass to further conversion to electricity, heat and liquid fuels. Different land-use scenarios are incorporated into the SRF processes (only direct land-use change, indirect land-use change with iLUC factor 25% or 50%, based on the methodology of Fritsche and Wiegmann [2008]).
GEMIS is valuable in several aspects:

1. GEMIS as data source (e.g. for reference systems, for instance for calculating the emission factor of the current electricity system. Data for electricity systems are available for several countries, including India and China.)
2. As mentioned above there is already a large number of SRF processes integrated (from cultivation to further conversion).
3. The GEMIS tool enables the user to modify processes and define new processes; thus it is possible to create a customised data basis.

In the first three sections of this report a methodology was presented which can be applied generally to the calculation of GHG balances for SRF (resp. for bioenergy crops in general). In this section the link to methodologies developed for CDM projects shall be explained.

Critical remark on studies done with GEMIS A drawback or at least a reductive temptation of the utilisation of GEMIS is that information on studies is reduced to charts or tables as obtained from the software tool without explaining in further text the according assumptions. The reader is left with the remark that the according data can be viewed using the GEMIS database. However for the case of the cultivation of SRF it was not possible to understand with sufficient certainty which assumptions have been made in Fritsche and Wiegmann [2008].

6 A brief overview on A/R CDM projects submitted so far

A valuable resource for A/R CDM project developers are Project Design Documents from A/R CDM projects submitted so far. All these documents are publicly available. Many lessons can be learned from reading how other project developers have taken into account the various conditions established within the CDM project cycle. In particular, it is very fruitful to look at the following passages within each document which are highly critical and difficult to tackle for each product development acording to generic guidlines:

1. How is it demonstrated that an area was not covered with forests before 1990? (eligibility of land)
2. How is leakage dealt with?
3. Which carbon pools are taken into account? Where are pools which are so far rather uncommon to take into account such as soil organic carbon and later? How is it justified not to take into account some pools?
4. How is monitoring done?
5. How is it achieved that soil opening is kept to a minimum?

Coppicing is relevant in one way or the other in the following A/R CDM projects. Tree species used for coppicing are listed at each entry of the list.

1. Agroforestry India (23) Eucaylptus spp. and Casuarina.
2. Albania (12): Mixed oak and hornbeam or Macedonian oak, ash and hornbeam.
3. Argos (21)
4. Bagepalli (28)
5. Chinchiná River (14)
6. Colombian Caribbean Savannah (27)
7. Humbo Ethiopia (11)
8. Northwest Guangxi (17)
9. Southern Nicaragua (26)
10. Plantar, Brazil (16)
11. Reforestation MTPL India (32)

Short rotation periods are in addition to the above projects - at least for selected tree species - in the following projects:

1. (Cao Phong (4):) In the project, however, a rather long term rotation period (15 years for both A. mangium and A. auriculiformis) was selected considering the rehabilitation and improvement of land productivity and expecting higher income for the participants by producing timber
2. Ibi Bateke (Congo) (22)

772.77686

(atbegshi) Package atbegshi Warning: Ignoring void shipout box

(b) Eucalyptus propagated via clonal propagation and

(c) Casuarina

2. 0: Leakage due to grazing is not considered as under the project, there will be increased production of fodder and as per the methodology it can be considered zero under conditions where the planned A/R CDM project activity produces more fodder, as is the case here.14

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3. The project covers plantations in two Indian states namely Orissa and Andhra Pradesh. These are two of the poorest states of India.

4. The cycle for harvesting the coppices is 5 to 6 years.

5. Expected fuel wood from branches and bark per hectare are about 10 tons which means an annual amount of about two tons per hectare. 1: Under the proposed CDM A/R project, branches of size smaller then 9cm are not collected but left for the farmer and this is approximately 10 to 15 tonnes per ha and this biomass from branches would be available to the farmers for use as fuelwood.44

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6. Not all shoots from coppicing trees are allowed to regrow after harvests. Only two or three strong shoots are allowed to grow and the remaining shoots are cut.

7. A large part of the works is done manually such as ploughing (using animals), weeding and harvesting, harvesting,

   (a) 2: The plantations are felled and debarked manually. The cutting is normally done using a manual saw but in some places mechanised saws may be used. The branches and twigs are retained by farmer for firewood. The main stem is debarked and cut to smaller lengths for transporting by truck, tractors, tucks or carts depending upon the distance.13

   (b) 3: The project also does not use machinery in site preparation, thinning and harvesting. Therefore, there are no emissions associated with the use of machinery in site preparation and logging.42

4: Ploughing: The land is ploughed with traditional plough or mould board plough. Generally ploughing is done manually and in very few cases farmers adopt mechanical ploughs. In case of slopy land, terracing is done to avoid soil loss. The frequency of ploughing depends upon the looseness of the soil.13

5: On most land parcels, farmers practice selective site preparation for planting. In situations where plough is used, the small farmers mostly use traditional plough that is used to suppress weeds within the rows of proposed planting area. Such disturbance does not significantly disturb the soil. Therefore, there is no significant influence of plough that could increase GHG emissions19

6: Fertilization: A dose of super phosphate and muriate of potash at 8 kg per hectare is applied two months after the planting.14

Sirsa (3)

Plantar, Brazil (16)

6.2 A list of A/R CDM projects submitted so far

Tab. 6.1: CDM A/R projects by 2012-01-06.

Nr.	Regis-tered	Title	Host Parties	Other Parties	Metho-dology	Reduct-ions	Ref	Deadw.	Litter	Soil org. C	SRF	Copp.
1	10/11/06	Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin	China	Canada Italy Luxembourg France Japan Spain	AR-AM0001 ver. 2	25,795	547	no	no	no		
2	30/01/09	Moldova Soil Conservation Project	Republic of Moldova	Canada Netherlands Italy Finland Luxembourg France Sweden United Kingdom of Great Britain and Northern Ireland Japan Norway Spain	AR-AM0002	179,242	1948	no	no	**yes**		
3	23/03/09	Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in Sirsa, Haryana	India		AR-AMS0001 ver. 4	11,596	2345	no	no	no	**yes**	
4	28/04/09	Cao Phong Reforestation Project	Vietnam		AR-AMS0001 ver. 4	2,665	2363	no	no	no	(**yes**)	
5	05/06/09	Reforestation of severely degraded landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry Project	India		AR-AM0001 ver. 2	57,792	2241	no	no	no	**yes**	
6	11/06/09	„Carbon Sequestration Through Reforestation In The Bolivian Tropics By Smallholders Of "The Federación de Comunidades Agropecuarias de Rurrenabaque (FECAR)"	Bolivia	Belgium	AR-AMS0001 ver. 4	4,341	2510	no	no	no		

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... **Tab. 6.1** continued.

Nr.	Registered	Title	Host Parties	Other Parties	Methodology	Reductions	Ref	Deadw.	Litter	Soil org. C	SRF	Copp.
7	21/08/09	Uganda Nile Basin Reforestation Project No.3	Uganda	Canada Japan Italy Spain France	AR-AMS0001 ver. 5	5,564	1578	no	no	no		
8	06/09/09	Reforestation of croplands and grasslands in low income communities of Paraguarí Department, Paraguay	Paraguay	Japan	AR-AMS0001 ver. 4	1,523	2694	no	no	no		
9	16/11/09	Afforestation and Reforestation on Degraded Lands in Northwest Sichuan, China	China		AR-AM0003 ver. 3	23,030	2700	no	no	no		
10	16/11/09	"Reforestation, sustainable production and carbon sequestration project in José Ignacio Távaras dry forest, Piura, Peru"	Peru		AR-AM0003 ver. 4	48,689	2715	no	no	no		
11	07/12/09	Humbo Ethiopia Assisted Natural Regeneration Project	Ethiopia	Canada Japan Italy Spain France	AR-AM0003 ver. 4	29,343	2712	no	no	no	**yes**	**yes**
12	01/01/10	Assisted Natural Regeneration of Degraded Lands in Albania	Albania	Canada Japan Italy Spain France	AR-AM0003 ver. 4	22,964	2714	no	no	no	**yes**	**yes**
13	15/01/10	The International Small Group and Tree Planting Program (TIST), Tamil Nadu, India	India	United Kingdom of Great Britain and Northern Ireland	AR-AMS0001 ver. 5	3,594	3000	no	no	no		
14	16/04/10	Forestry Project for the Basin of the Chinchiná River, an Environmental and Productive Alternative for the City and the Region	Colombia		AR-AM0004 ver. 3	37,783	2996	no	no	no	**yes**	**yes**

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... **Tab. 6.1** continued.

Nr.	Regis-tered	Title	Host Parties	Other Parties	Metho-dology	Reduct-ions	Ref	Deadw.	Litter	Soil org. C	SRF	Copp.
15	27/05/10	Nerquihue Small-Scale CDM Afforestation Project using Mycorrhizal Inoculation in Chile	Chile	United Kingdom of Great Britain and Northern Ireland	AR-AMS0001 ver. 5	9,292	3338	no	no	no		
16	21/07/10	Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil	Brazil	Netherlands	AR-AM0005	75,783	2569	no	no	no	**yes**	**yes**
17	15/09/10	Reforestation on Degraded Lands in Northwest Guangxi	China	Spain	AR-ACM0001 ver. 3	87,308	3561	no	no	**yes**	**yes**	**yes**
18	03/12/10	Posco Uruguay' afforestation on degraded extensive grazing land	Uruguay		AR-ACM0001 ver. 3	21,957	3845	**yes**	**yes**	no		
19	07/01/11	AES Tietê Afforestation/Reforestation Project in the State of São Paulo, Brazil	Brazil	Canada Japan Italy Spain France	AR-AM0010 ver. 4	157,635	3887	no	no	no		
20	11/02/11	Reforestation of grazing Lands in Santo Domingo, Argentina	Argentina	Switzerland	AR-AM0005 ver. 3	66,038	4127	no	no	no		
21	17/02/11	Argos CO2 Offset Project, through reforestation activities for commercial use	Colombia	United Kingdom of Great Britain and Northern Ireland	AR-AM0005 ver. 3	36,930	3233	no	no	no		
22	18/02/11	Ibi Batéké degraded savannah afforestation project for fuelwood production (Democratic Republic of Congo)	Democratic Republic of the Congo	France	AR-ACM0001 ver. 3	54,511	4176	no	no	no	**yes**	

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… **Tab. 6.1** continued.

Nr.	Registered	Title	Host Parties	Other Parties	Methodology	Reductions	Ref	Deadw.	Litter	Soil org. C	SRF	Copp.
23	28/02/11	Improving Rural Livelihoods Through Carbon Sequestration By Adopting Environment Friendly Technology based Agroforestry Practices	India	Canada Japan Italy Spain France	AR-AM0004 ver. 3	4,896	4531	no	no	no	**yes**	**yes**
24	04/03/11	India: Himachal Pradesh Reforestation Project – Improving Livelihoods and Watersheds	India	Spain	AR-ACM0001 ver. 3	41,400	4174	no	no	no		
25	04/04/11	Kachung Forest Project: Afforestation on Degraded Lands	Uganda	Sweden	AR-AM0004 ver. 4	24,702	4653	no	no	no		
26	07/05/11	Southern Nicaragua CDM Reforestation Project	Nicaragua	Canada Japan Italy Spain France	AR-AMS0001 ver. 5	7,915	3970	no	no	no	**yes**	**yes**
27	26/05/11	Forestry Project in Strategic Ecological Areas of the Colombian Caribbean Savannas	Colombia		AR-AM0005 ver. 3	66,652	4595	no	no	no	**yes**	**yes**
28	27/05/11	Bagepalli CDM Reforestation Programme	India		AR-AM0004 ver. 4	92,103	4851	no	no	no	**yes**	**yes**
29	07/06/11	Commercial reforestation on lands dedicated to extensive cattle grazing activities in the region of Magdalena Bajo Seco	Colombia		AR-AM0004 ver. 4	32,965	4861	no	no	no	(**yes**)	
30	11/06/11	Aberdare Range/ Mt. Kenya Small Scale Reforestation Initiative Kamae-Kipipiri Small Scale A/R Project	Kenya	Canada Japan Italy Spain France	AR-AMS0001 ver. 5	8,542	3206	no	no	no		

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… **Tab. 6.1** continued.

Nr.	Registered	Title	Host Parties	Other Parties	Methodology	Reductions	Ref	Deadw.	Litter	Soil org. C	SRF	Copp.
31	20/06/11	Uganda Nile Basin Reforestation Project No.5	Uganda	Italy	AR-AMS0001 ver. 5	5,925	4466	no	no	no		
32	01/08/11	Reforestation of degraded land by MTPL in India	India		AR-ACM0001 ver. 4	146,998	5016	no	no	**yes**	**yes**	**yes**
33	23/08/11	Uganda Nile Basin Reforestation Project No 2	Uganda	Italy	AR-AMS0001 ver. 5	4,861	4940	no	no	no		
34	23/08/11	Uganda Nile Basin Reforestation Project No 1	Uganda	Italy	AR-AMS0001 ver. 5	5,881	4939	no	no	no		
35	29/08/11	Uganda Nile Basin Reforestation Project No 4	Uganda	Italy	AR-AMS0001 ver. 5	3,969	4941	no	no	no		
36	05/10/11	Aberdare Range / Mt. Kenya Small Scale Reforestation Initiative Kirimara-Kithithina Small Scale A/R Project	Kenya	Canada	AR-AMS0001 ver. 5	8,809	3207	no	no	no		
		total				**1,418,993**		**1**	**1**	**3**	**13**	**10**

End of **Tab. 6.1**: CDM A/R projects by 2012-01-06.
CO2AgricultureForestryEmissionTables.*CDMARProjects*

7 Leakage as dealt with in A/R CDM projects submitted so far

Effects from indirect land-use change are considered in A/R CDM projects under the term 'leakage'.

'Leakage is the increase in GHG emissions occurring outside the project boundary of an A/R CDM project activity which is measurable and attributable to the activity.' (Pearson et al. [2005], 56).

Leakage can take place due to displaced agricultural and cattle raising activities. Displaced farmers could cut forests elsewhere to continue their activities.
The methodologies for A/R CDM projects presented in the CDM Methodology Booklet (UNFCCC [2010]) include in the section 'Important conditions under which the methodology is applicable' the passage: 'No leakage: the project does not lead to a shift of pre-project activities outside the project boundary.' (UNFCCC [2010], 190ff.) That means that the project developers have to assure that no leakage occurs resp. that the risk of leakage is minimised or leakage is taken into account in the emission balance calculation. In particular, what regards the behavior of *people affected by the project* (affected livelihoods), in the 'Sourcebook for Land Use, Land-Use Change and Forestry Projects' (Pearson et al. [2005], p. 37) a decision tree is depicted which shall help to identify whether according leakage is likely to occur and what form the leakage might take (**Fig. 7.1**).
Three different categories of leakage (activity shifting, market effects, super-acceptance) are considered (Pearson et al. [2005], 36):

Activity shifting occurs when activities that cause emissions are not permanently avoided, but are simply displaced to another area.
Example:
If one area is set aside for reforestation, cattle farmers who were farming the area might deforest an alternative area outside the project boundaries to replace their lost grazing land.

Market effects occur when emission reductions are countered by emissions created by shifts in supply and demand of the products and services affected by the project. This is of minimal importance for farming activities, but can be important for large-scale commercial timber harvesting.
Example:
A stop-logging project might decrease the supply of timber, leading other practitioners to increase their rate of harvest. Market effects leakage is not likely to be a problem, however, for afforestation/reforestation project activities because supply is actually increased in the majority of cases rather than decreased.

Super-acceptance may result from the alternative livelihoods activities created for the project. If the activities are very successful, they can draw in people from the surrounding regions. The result may be positive or negative leakage. It will be positive if the immigrants were previously deforesting or practising a similarly high GHG-emitting lifestyle, but negative if the immigrants previously had lower GHG-emitting lifestyles and now have access to new land, for example, to deforest.

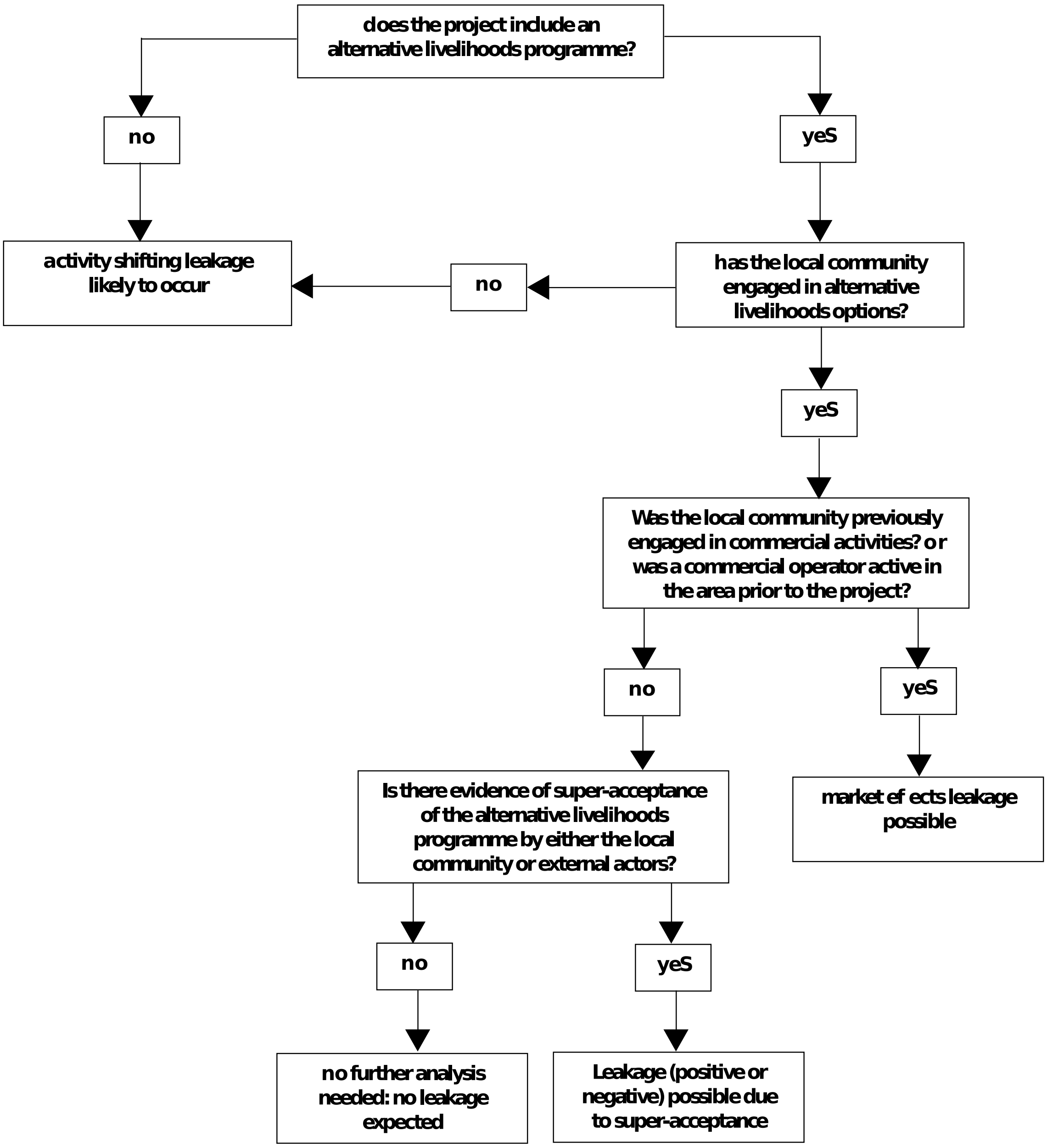

Fig. 7.1: Decision tree regarding leakage with regard to the livelihoods of people affected by the project. Source: Pearson et al. [2005], p. 37.

7.1 Leakage as taken from some projects

Aberdare Range Kamae Kipipiri (30) Leakage

Justification why leakage has not been taken into account:

1. there are no displaced households within the project boundary;
2. displaced agricultural production (fodder collection) from within the project boundary is minimized by allowing this activity to continue between the planted trees;
3. displaced agricultural production (fodder collection) is compensated by promotion of improved grassland management techniques (zero-grazing); and
4. the remaining displaced agricultural production (fodder collection) cannot cause deforestation since all remaining forests are protected by law.

(same arguments in Aberdare Range Kirimara Kithithina (36))

AES Tiete (19) Leakage zero.

Agroforestry India (23) Leakage zero.
However, some leakage is expected from the project activity due to transportation of the wood from the project sites to the paper mill, which is the buyer of the wood. Awareness programmes are beingconducted for the participating farmers to minimize the use of fossil fuels which will result in the GHG emissions and they will be encouraged to use common transportation facilities, conventional transport such as bullock carts, use of biofuels etc to reduce the emission levels.

Albania (12) Leakage zero.

Argos (21) Leakage 23,100 versus 36,930.5

Bagepalli (28) Leakage zero.

Cao Phong (4) Leakage from displacement of cropland and of grazing land taken into account. 11,090 versus 42,645

Rurrenabaque (6) Leakage through activity shifting will occur since cattle will be displaced to areas outside the project boundary. 24,124 versus 91,165

Paraguari (8) Leakage due to grazing and cropland is taken into account. 18,983 versus 30,468

Chinchiná River (14) Leakage zero.

Colombian Caribbean Savannah (27) Leakage zero.

Guangxi (1) Leakage as from the transport with diesel trucks. It is astounding that this amounts to 19,852 t at the end of the crediting period (30 years).

Humbo Ethiopia (11) Leakage zero.

Ibi Bateke (Congo) (22) Leakage zero.

Himachal Pradesh (24) Leakage zero.

Kachung (25) Leakage due to displacing cropland.

Khammam (5) Leakage due to transportation.

Magdalena Bajo Seco (29) Leakage zero.

Moldova (2) Leakage due to transportation.

Nerquihue (15) Leakage zero.

Northwest Guangxi (17) Leakage zero.

Posco Uruguay (18) Leakage zero.

Southern Nicaragua (26) Leakage zero.

Uganda Nile Basin (7) Leakage zero.

Piura (10) Leakage zero.

Plantar, Brazil (16) Leakage due to transportation.

Reforestation MTPL India (32) Leakage zero.

Santo Domingo, Argentina (20) Leakage zero.

Sichuan (9) Leakage due to transportation.

Sirsa (3) Leakage zero.

Tamil Nadu (13) Leakage zero.

UgandaNileBasin 1 (34) Leakage zero.

UgandaNileBasin 2 (33) Leakage zero.

UgandaNileBasin 4 (35) Leakage zero.

Uganda Nile Basin 5 (31) Leakage zero.

7.2 UNFCCC Tools for leakage

The CDM Methodology Booklet lists two tools which deal (in some way) with leakage (UNFCCC, 186ff.):

1. *Tool for testing significance of GHG emissions* in A/R CDM project activities

   This tool facilitates the determination of significance for GHG emissions by sources, decreases in carbon pools, or leakage emissions for a particular A/R CDM project. Regarding leakage emissions the following procedure is proposed: 'Estimate leakage emissions per activity based on site/project specific data, scientific literature, or the most recent default emission factors provided by IPCC (e.g. IPCC 1997, 2003, 2006) and site/project specific activities. Estimation shall follow the approved methodology.' (UNFCCC/CCNUCC: Tool for testing significance of GHG emissions in A/R CDM project activities (Version 01). EB 31)

2. Estimation of the increase in GHG emissions attributable to *displacement of pre-project agricultural activities* in A/R CDM project activity

   This tool is applicable for estimating the increase of GHG emissions attributable to the displacement of pre-project agricultural activities ('leakage") due to implementation of an A/R CDM project activity, which cannot be considered insignificant (using the respective guidelines). It is not applicable if the displacement of agricultural activities attributable to the A/R CDM project is expected to cause any drainage of wetlands or peatlands. This tool supersedes the A/R methodological tool 'Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity" on 4 June 2011.

7.3 Leakage as it may be treated in small scale A/R CDM projects according to the UNFCCC

The UNFCCC document 'Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories' provides guidance on how emissions from production of the biomass and leakage should be treated.
The following table from this document shows which categories of emission sources (shift of pre-project activities, emissions from biomass generation/cultivation, competing use of biomass) are relevant for different biomass types.

Biomass type	Activity / source	Shift of pre-project activities	Emissions from biomass generation / cultivation	Competing use of biomass
Biomass from forests	Existing forests	-	-	x
	New forests	x	x	-
Biomass from croplands or grasslands (woody or non-woody)	In the absence of the project the land would be used as cropland / wetland	x	x	-
	In the absence of the project the land would be abandoned	-	x	-
Biomass residues or wastes	Biomass residues or wastes are collected and used	-	-	x

Fig. 7.2: Relevant emission source per type of biomass. Source: UNFCCC/CCNUCC: 'Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories'

In the following some excerpts of this document are presented.

Shifts of pre-project activities [...] As a first guidance, project participants may neglect leakage effects due to shifts in pre-project activities, where the land would not be used or where the land use (inside the project boundary) does not change as a result of the project activity. [...] Project participants should assess the possibility of leakage from the displacement of activities or people considering the following indicators:

1. Percentage of families/households of the community involved in or affected by the project activity displaced (from within to out of the project boundary) due to the project activity;

2. Percentage of total production of the main produce (e.g. meat, corn) within the project boundary displaced due to the generation of renewable biomass.

If the value of these two indicators is lower than 10%, then leakage from this source is assumed to be zero. If the value of any of these two indicators is higher than 10% and less than or equal to 50%, then leakage shall be equal to 15% of the difference between baseline emissions and project emissions. If the value of any of these two indicators is larger than 50%, then this methodology is not applicable.

Emissions from the production of the renewable biomass Potentially significant emission sources from the production of renewable biomass can be:

1. Emissions from application of fertilizer; and
2. Project emissions from clearance of lands.

These emissions sources should respectively be included in a simplified manner, not involving any significant transaction costs. All other emission sources are likely to be smaller than 10% (each) - including transportation of raw materials and biomass, fossil fuel consumption for the cultivation of plantations - and can therefore be neglected in the context of SSC project activities. [...]

Competing uses for the biomass [...] The project participant shall evaluate if there is a surplus of the biomass in the region of the project activity, which is not utilised. If it is demonstrated that the quantity of available biomass in the region, is at least 25% larger than the quantity of biomass that is utilised including the project activity, then this source of leakage can be neglected otherwise this leakage shall be estimated and deducted from the emission reductions.

To summarise the contents of this section, it becomes evident that the UNFCCC is aware of the diverse potential sources of GHG emissions that may be caused by A/R and other types of CDM projects deploying bioenergy. Here we discussed especially the role of leakage and how it is incorporated in the CDM methodologies. Even if CDM projects may be exemplary we should be aware that the greater share of bioenergy production takes place outside CDM projects, also in developing countries. We also have to ask the question how thoroughly are CDM projects controlled and monitored and how high the potential to misuse the CDM programme (by free-riders) might be.

8 Green house gases from the usage of the wood

Potential GHG emissions reductions from substituting fossil fuels by using wood from SRF plantations for electricity and/or heat production are not considered within A/R CDM projects. CDM projects cover a large range of activitities to reduce GHG emissions so substitution of fossil fuels by biomass is relevant for some (other) types of CDM projects. Coming back to the methodology for calculating GHG emissions the substitution effect of fossil fuels (section 1, point 1) is taken into account in such CDM projects. The baseline GHG emissions (= emissions under the assumption that the CDM project is not carried out) have to be calculated. To fulfill this task certain standardised methodologies (like 'Tool to calculate the emission factor for an electricity system', UNFCCC/CCNUCC [2011]) exist.
But how are the emissions caused by biomass production and land-use change treated in such projects? The project type 'AM0042 Grid-connected electricity generation using biomass from newly developed dedicated plantations' (UNFCCC [2010], 59) has a direct

relation to SRF. Leakage effects are minimised because such a project may only be developed under the condition that the land area where the dedicated plantation will be established has not been used for any agricultural or forestry activity prior to the project implementation. For some project types only biomass residues are allowed (like 'AM0085 Co-firing of biomass residues for electricity generation in grid connected power plants'[8]) or biomass is excluded (like 'AM0019 Renewable energy projects replacing part of the electricity production of one single fossil fuel fired power plant that stands alone or supplies to a grid, excluding biomass projects').
For some project types only renewable biomass may be deployed (like 'AMS-I.C. Thermal energy production with or without electricity').[9]

9 Research requirements

The following is a literal excerpt from Galinski [2011], a slide presentation on research needs in A/R CDM projects held by Dr. Wojtek Galinski, team lead of the A/R CDM unit at the UNFCCC. An according audio file where you can listen to the entire presentation as it was held will probably as well be published at http://www.benwood.eu once the file has received the according release permit by Dr. Galinski.

9.1 Eligibility of land

Areas:

- Credible and cost-effective means of demonstrating eligibility of land
- Regional eligibility of land

Questions:

1. Development of innovative methods for merging incomplete remote sensing data with incomplete ground truth data (possibly collected in another region of similar ecology and land management) in order to estimate at least crown cover and height of trees in areas of land planned for project activity since end of 1989
2. Development of statistical approaches to describe land use patterns allowing for determination of the share of forest at the end of 1989 at the local level
3. Development of innovative methods applicable to large areas for determination of the share of forest at the end of 1989
4. Development of participatory appraisal techniques for quantitative identification of land-use and trends in land-use

[8] All examples are taken from the 'CDM Methodology Booklet' (UNFCCC [2010]).

[9] The definition of renewable biomass by the UNFCCC consists of five conditions whereas condition 2 is relevant for SRF (UNFCCC/CCNUCC. Annex 18. Definition of renewable biomass): The biomass is woody biomass and originates from croplands and/or grasslands where: (a) The land area remains cropland and/or grasslands or is reverted to forest; and (b) Sustainable management practices are undertaken on these land areas to ensure in particular that the level of carbon stocks on these land areas does not systematically decrease over time (carbon stocks may temporarily decrease due to harvesting); and (c) Any national or regional forestry, agriculture and nature conservation regulations are complied with.

9.2 Determination of the baseline

Areas:

- To facilitate building up a credible and complete list of baseline scenarios
- To improve accuracy of baseline tree biomass estimation
- To develop regional standardized baseline

Questions:

1. The assessment of the impact of land-use and land-tenure legislation on land management decisions in developing countries
2. Simple models of land-use dynamics in developing countries applicable at local scale
3. The development of regional default data related to tree/shrub biomass and its growth taking into account different types of management, different crown cover and species

9.3 Demonstration of additionality

Area:

- Development of innovative approaches for demonstration of additionality

Questions:

1. Identification of elements affecting the decision on forestation of an area of land and development of a simple model allowing for the identification of CDM impact on decision making
2. Development of a standardized approach for financial analysis of A/R projects based on typical projection of incomes and costs over the duration of the project and including A/R specific elements, e.g. value of land and residual value of project

Area:

- Facilitation of evaluation of barrier analysis of A/R projects

Question:

1. Development of standardized methods for collecting data on barriers faced by the proposed project activity and the assessment of their impact on decision making for the forestation of an area of land

9.4 Estimation of changes in carbon pools

	1	2
	Carbon pool	**Importance**
1	Above-ground biomass	Major
2	Below-ground biomass	Major
3	Dead wood	Possibly significant
4	Litter	Possibly insignificant
5	Soil organic carbon	Possibly significant

CO2AgricultureForestryEmissionTables.*ResearchNeedsUNFCCC2011*

Tab. 9.1: Importance of future research by carbon pool as expressed by Dr. Galinski from the A/R CDM team of the UNFCCC in Barolo, nothern Italy in June 2011.

9.5 Estimation of changes in above-ground biomass

1. Regionally applicable defaults (standardized baselines):
   (a) Rates of pre project biomass accumulation
   (b) Data on pre project biomass
2. Database of allometric equations for estimation of tree biomass
3. Methods for cost effective development of allometric equations
4. Simple innovative methods for estimating above-ground biomass in mangrove forests and shrubs or appropriate default data

How it helps:
To facilitate cost-effective and accurate / conservative estimation of tree biomass

9.6 Estimation of changes in below-ground biomass

1. Database of default root-to-shoot ratios for different species / group of species possibly by age-classes
2. Innovative methods for estimation root biomass in mangrove forests
3. Root-to-shoot ratio in coppice forests

How it helps:
To facilitate cost-effective and accurate estimation of tree biomass

9.7 Estimation of changes in dead wood

1. Simple indirect methods for field estimation of dead wood
2. Conservative default ratios between dead wood biomass and aboveground biomass of trees
3. Simple indirect methods for field estimation of share of wood in different classes of decay or a conservative default on it

How it helps:
To facilitate cost-effective estimation of dead wood biomass

9.8 Estimation of changes in litter

1. Indirect methods for field estimation of litter
2. Conservative default ratios between litter biomass and aboveground biomass of trees

How it helps:
To facilitate cost-effective estimation of litter biomass

9.9 Estimation of changes in soil organic carbon

1. Indirect methods for field estimation of soil organic carbon
2. Conservative defaults for estimation of changes in soil organic carbon after typical / special management practices / soil disturbances
3. Rates of change in soil organic carbon in lands under plantations
4. Indirect methods for field estimation of / conservative defaults for changes in sediment organic carbon in mangrove forests

How it helps: To facilitate cost-effective estimation of soil / sediment organic carbon

10 A critical view on the CDM project scheme

How efficient is it to allocate financial means to A/R CDM projects at an international scale by the Kyoto scheme?
From talks held within the Benwood project, especially impressions taken from the final conference in Italy in 2011, it resulted that the 'CDM layer' on A/R projects is still regarded as something which is in its infancy, which is 'nice to have' as an additional input to a project - which would happen anyway.

Obviously, this perception is in total contradiction with the concept of additionality as it is foreseen within the flexible mechanisms of the Kyoto Protocol. However it may be, this seems to be the perception of major stakeholders involved in A/R projects.

There has to be space in this document to formulate the question if the CDM cycle and the Kyoto Protocol this is really the most efficient means in order to increase global carbon stocks on woody biomass. Other means would be to convince farmers that trees are a direct benefit for them in their daily lives independently from the circumstance if there a CDM scheme exists or not. One of the research questions formulated by the UNFCCC is to understand what farmers think and plan. This question alone has an inherent enormous uncertainty, especially when looking at projects of a lifetime (crediting period) of around 20 years or more. In order to take account of changes in the development of framing conditions and assumptions a project is based on, further concepts are foreseen within the CDM scheme such as monitoring of the project activities on the one hand and, in some cases, also monitoring of the according baseline and according revisions.

However, the efforts for ensuring additionality by these means are high. Actually, the bulk of large SRF plantations in the recent years in India have not been developed because of the CDM cycle but because there is a strong shortage of wood and major stakeholders within the country have come together and developed a program which should ensure the future supply of wood. As it seems, stakeholders also try to benefit rightfully from the CDM cycle making their first steps by submitting according projects within the CDM scheme. But definitely, this is not the case for the majority of areas planted with trees. The real driver rather is to create a situation for farmers convincing enough in terms of simple but longterm contractual conditions at a local basis, clear long term ecologic benefit (e.g. with regard to soil fertility and water regime), providing the necessary infrastructural help in terms of genetic material, consulting and attractive buying contracts.

A Energy demand of human beings, animals and agricultural machinery, associated carbon emissions

Human beings

		1	2	3	4	5	6	7	8	9	10
	Age in months/years	**Persons with BMI within standard range**				**Individual physical activity**					
						low		medium		intense	
		MJ/day		kcal/day		kcal/kg body mass					
		m	f	m	f	m	f	m	f	m	f
	Babies										
1	0 to 4 months	2,0	1,9	500	450			94	91		
2	4 to 12 months	3,0	2,9	700	700			90	91		
	Children										
3	1 to 4	4,7	4,4	1,100	1,000	83	80	91	88	5)	5)
4	4 to 7	6,4	5,8	1,500	1,400	74	70	82	78	5)	5)
5	7 to 10	7,9	7,1	1,900	1,700	66	60	75	68	83	76
6	10 to 13	9,4	8,5	2,300	2,000	56	49	64	55	71	62
7	13 to 15	11,2	9,4	2,700	2,200	50	41	56	47	63	52
	Youngsters und adults										
8	15 to 19	13,0	10,5	3,100	2,500	39	36	46	43	60	55
9	19 to 25	12,5	10,0	3,000	2,400	35	33	41	40	54	51
10	25 to 51	12,0	9,5	2,900	2,300	34	33	39	39	52	50
11	51 to 65	10,5	8,5	2,500	2,000	32	32	35	35	48	48
12	65 and more	9,5	7,5	2,300	1,800	30	30	34	33	46	46

foodKeyFigures.*EnergieZufuhrDeutschlandDACH*

Tab. A.1: Guidance values for average daily energy input for human beings in Germany. Source: Landesstelle für landwirtschaftliche Marktkunde Schwäbisch Gmünd [2007].

According to **Tab. A.1** the human body mass specific energy demands for male persons within the age class 25-51 years are:

1. at a low activity: 34 kcal/kg

2. at an intense activity: 52 kcal/kg

The difference between low and intense activity is: 52-34 = 18 kcal/kg body mass. One could understand by this the maximum energy value which is required for performing work.

For a person of 70 kg body mass this results in 18 kcal/kg $\times$ 70 kg = 1260 kcal/day/person (1.260 $\times$ 4.182= 5.27 MJ/day/person) to be supplied via food to compensate for metabolic energy conversion due to hard work.

This amount corresponds to a little bit less than half of the average daily food demand. This energy demand is satisfied by food in Austria (average food diet of a person) as shown in **Tab. A.2**:

	1	2
	product	kg/a/cap
1	beer	112
2	vegetables	103
3	meat	99
4	milk	96
5	fruits	96
6	cereals	84
7	potatoes	53
8	wine	28
9	cheese	18
10	eggs	14
11	butter	5
12	total	705

foodKeyFigures.*foodConsumptionAustria*

Tab. A.2: Average annual food diet of an Austrian inhabitant by food categories. Source: Österreichisches Lebensministerium [2005]

However again this is a circle analysis in the sense that the CO_2 emissions for food in turn depend on the cultivation methods for food.

B Carbon pools to be monitored in large scale A/R CDM projects

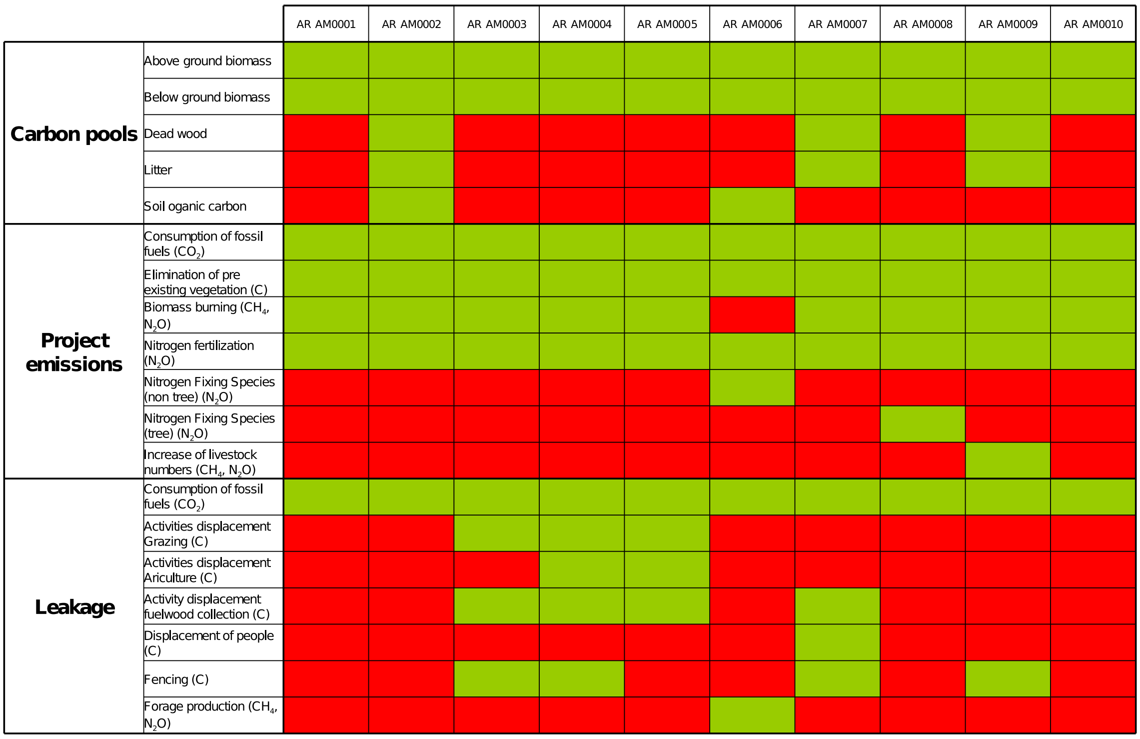

Fig. B.1: Carbon pools to be monitored in large scale A/R CDM projects as of April 2010. Source: Martins Vieira Coelho Ferreira [2010]. There stated to be taken from the software TARAM 1.3.

C Data on carbon content of some tree species in India

In the following some data on the carbon content of tree genus are provided. All data is taken from articles which are contained in Indian Ecological Society [2011]. This document has been prepared in 2011 after a IUFRO event after which also a training has been held which was supported by Benwood. The entire document may be downloaded from http://www.benwood.eu.

	1	2	3	4	5	6
		Tree height (m)				
1	Diameter at breast height (cm)	15	17	20	22	24
2	12	26.6	29.4	33.7	36.3	39.1
3	15	41.2	45.6	52.2	56.5	60.7
4	17	52.6	58.4	66.7	72.2	77.6
5	20	72.4	80.3	91.8	99.4	106.8
6	25	112.2	124.5	142.4	154	165.5
7	30	160.6	178.1	203.7	220.3	236.8

tabSpecialIssueIndianJournalOfEcology2011.*carbonSequesteredInEucalyptus*

Tab. C.1: Amount of carbon sequestered (kg) in eucalyptus trees. Values obtained from trials in Punjab/Northern India. Source: Dogra [2011].

	1	2	3	4	5	6
		Tree height (m)				
1	Diameter at breast height (cm)	**16**	**18**	**20**	**22**	**24**
2	18	32.41	34.66	36.82	38.91	*
3	20	36.56	39.14	41.63	44.04	46.37
4	22	40.84	43.78	46.6	49.34	51.98
5	24	45.26	48.55	51.73	54.79	57.76

tabSpecialIssueIndianJournalOfEcology2011.*carbonSequesteredInPoplar*

Tab. C.2: Amount of carbon sequestered (kg) in poplar trees. Values obtained from trials in Punjab/Northern India. Source: Dogra [2011].

	1	2	3
	Species	**Mean tree (kg)**	**Per ha (Mg ha)**
1	Albizia procera	169.58	189.93
2	Casuarina equisetifolia	165.94	185.85
3	Eucalyptus tereticornis	102.1	114.36
4	Gmelina arborea	17.19	19.25
5	Mean	113.7	127.35
6	LSD at 1%	44.36	49.68
7	CV %	24.39	24.39

tabSpecialIssueIndianJournalOfEcology2011.*carbonSequestrationPotential*

Tab. C.3: Carbon sequestration potential of 20-year-old multipurpose (MPT) trees. Source: Madhusudanan et al. [2011].

	1	2	3
	Species	**Mean tree biomass (kg)**	**Total aboveground biomass**
1	Albizia procera	339.16	379.86
2	Casuarina equisetifolia	331.81	371.7
3	Eucalyptus tereticornis	204.23	228.73
4	Gmelina arborea	34.37	38.49
5	Mean	227.41	254.69
6	LSD at 1%	88.72	99.37
7	CV %	24.39	24.39

tabSpecialIssueIndianJournalOfEcology2011.*aboveGroundBiomassTwentyYearMPtrees*

Tab. C.4: Aboveground biomass of 20-year-old multipurpose (MPT) trees. Source: Madhusudanan et al. [2011].

	1	2	3
	Species	**Organic carbon (%)**	**Soil organic carbon (Mg ha-1)**
1	Albizia procera	1.35	54.87
2	Casuarina equisetifolia	1.79	69.54
3	Eucalyptus tereticornis	1.12	41.69
4	Gmelina arborea	0.68	29.85
5	Mean	0.46	21.87
6	Mean	1.07	43.56
7	LSD at 1%	0.03	0.84
8	CV %	1.9	126

tabSpecialIssueIndianJournalOfEcology2011.*soilCarbonTwentyYearMultipurposeTrees*

Tab. C.5: Soil carbon sequestration contribution of 20-year-old multipurpose (MPT) trees. Source: Madhusudanan et al. [2011].

D Pictures of tree root systems in northern India

Fig. D.1.a: Acacia catechu

Fig. D.1.b: Acacia nilotica

Fig. D.1.c: Acrocarpus fraxinifolius

Fig. D.1.d: Anthocephalus Kadamba

Fig. D.1.e: Bombax ceiba

Fig. D.1.f: Dalbergia sissoo

Fig. D.1.g: Eucalyptus tereticornis

Fig. D.1.h: Gmelina arborea

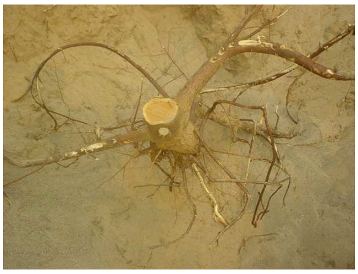

Fig. D.1.i: Melia azedarach

Fig. D.1.j: Populus deltoides

Fig. D.1.k: Syzygium cumini

Fig. D.1.l: Terminalia arjuna

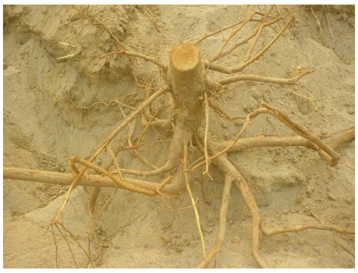

Fig. D.1.m: Toona ciliate

Fig. D.1: Root systems of various tree species. All photographs contributed by Chauhan.

Glossary

CO_2-eq The amount of CO_2 as a mass equivalent (mostly specified in tons or kg CO_2) to the mass of other GHGs. 10, 21

A/R afforestation and reforestation. 7, 8, 14, 25, 26, 31, 40, 43–45

above-ground biomass From the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: 'All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage.

Note: In cases where forest understory is a relatively small component of the above-ground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series'. 7, 56

agroforestry *Agroforestry is a collective name for land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals* '*on the same land management unit. The integration can be either in spatial mixture or temporal sequence. There are normally both ecological and economic interactions between the woody and non-woody components in agroforestry.*' (ICRAF (International Centre for Research on Agroforestry) [2010]). Fast-growing trees grown in SRF can be part(s) of an agroforestry system

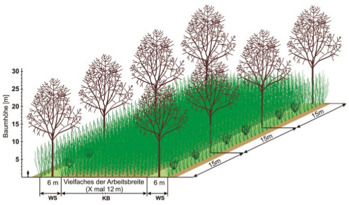

Fig. 4.2: Agroforestry (Morhart et al. [2010])

. 57

Annex I Countries 'Annex' refers to the according Annex I of the UNFCCC. Countries listed in the annex signed and ratified the Convention. Having signed and ratified also the Kyoto Protocol these countries have to submit accordingly inventories on their emission performance.A literal explanation of 'Annex I' as drawn from a publication of the secretariate of the UNFCCC (UNFCCC (United Nations Framework Convention on Climate Change) [2008a]) is: '*The annex to the Convention specifying which developed country Parties and other Parties to the Convention have committed themselves to limiting anthropogenic emissions and enhancing their GHG sinks and reservoirs*'. The complete list of these countries can be found at the website of the UNFCCC secretariate at http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php. 6, 11, 16, 17, 26, 58, 59

below-ground biomass From the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: 'All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter (litter fall or forest floor).' The is assessed simply by multiplying the above-ground biomass with a constant factor, the root-to-shoot ratio. 7

biochar Based on Verheijen et al. [2010]:

1. biochar understood as a *concept* in soil improvement: 'charcoal (biomass that has been pyrolysed in a zero or low oxygen environment) for which, owing to its inherent properties, scientific consensus exists that application to soil at a specific site is expected to sustainably sequester carbon and concurrently improve soil functions (under current and future management), while avoiding short- and long-term detrimental effects to the wider environment as well as human and animal health.'
2. biochar understood as a *material*: the charcoal itself that is integrated into soil in order to raise its carbon content

. See also terra preta. 8, 62

carbon content From the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: 'Absolute amount of carbon in a carbon pool or parts of it'. 52

carbon pool From the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: 'A reservoir. A system which has the capacity to accumulate or release carbon. Examples of carbon pools are forest biomass, wood products, soils, and the atmosphere. The units are in mass'. Adapted from Penman et al. [2003]: National circumstances may lead to slight differences in pool definitions. Where definitions different from those in Penman et al. [2003] are used, it is good practice to report upon them clearly. 7, 8, 31, 43, 55, 56

CDM methodology A project development methodology eligible for the development of a CDM project. In particular such methodologies describe eligible approaches how the *carbon impact* of a project may be calculated as well as, in general, how environmental integrity may be guaranteed. 'Eligible' means that they have been approved by the according Executive Board. An overview on available CDM methodologies can be found here `http://cdm.unfccc.int/methodologies/index.html` and are summarized as a printable in UNFCCC [2010]. Since methodologies are continuously updated one should always consult the website. 7, 26, 59

Clean Development Mechanism (CDM) As a westernised state, e. g. Germany, take some money and provide it as a sponsor to somebody who replaces the coal-firing of a power plant in India by biomass firing. This project reduces the CO_2 emissions of that power plant in India with a co-financing by German money. The according emission reduction is accounted for in your national balance, i.e. in the balance of the state who has provided the co-financing to the project. You do this as a state because with the same amount of money you would have achieved less emission reductions with a project in your own country (measures achieving the same CO_2 reduction would have been much more expensive). In reality there are several actors involved in such a project, such as foremost a *project developer* who also trades the according emission reductions on an international market. This project-based trade in GHG emission reductions across countries is the logics of so called CDM projects. This project type is foreseen in the Kyoto Protocol as an eligible means of westernised countries to fulfil part of their emission reduction obligations. Within Europe and also in other regions of the world according internal trading schemes and obligations have been established in line with the Kyoto Protocol framework. India, in the above example is called a 'host country' (hosting the project). 25, 26, 31, 40, 43–45, 57, 60

dead wood Adapted from IPCC (Intergovernmental Panel on Climate Change) [2006]: 'Dead wood encompasses coarse woody debris, dead coarse roots, standing dead trees, and other dead material not included in the litter or soil organic carbon' and from the glossary part of the document: 'Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10cm in diameter (or the diameter specified by the country)'. 7, 8, 59

degraded land A wide variety of definitions is used in the literature, see further UNE (UNE 2008). One of these definitions is: land where the balance between the attacking forces of climate and the natural resistance of the terrain against these forces has been broken by human intervention, resulting in a decreased current and/or future capacity of the soil to support human life. These and most other definitions imply that crop yields on degraded areas are reduced compared to fertile soils, although this aspect is usually not included in the definition. Note that this definition (partially) overlaps with the definition of marginal land that is given below. Source: Oldeman [1994]. 6

denitrification An anaerobic process. The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen (dinitrogen N_2) or as an oxide of nitrogen (adapted from the glossary of Anonymous [2000]). 17, 59

diameter at breast height (DBH) Diameter of the stem of a tree measured at breast height which is agreed to be at 130 cm above ground level. It is a very good parameter for a rough estimation of the wood volume of a tree (potentially complemented by the information on the tree height.) For example, a spruce of 26 m height and a DBH of 33 cm provides wood by the amount of roughly one stère (Source: Forst-Platte-Papier [2002]). 7

GEMIS A software, developed in Germany in order to assess the effects of the supply of useful energy. E. g. to understand how many emissions of SO_2 have been induced by the consumption of one kWh of electricity in a country. 27, 30

green house gas (GHG) Any gas contributing to the global green house effect. In a stricter sense the six gasses as listed in Annex A of the Kyoto Protocol:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous oxide (NO_2)
4. Hydrofluorocarbons (HFCs)
5. Perfluorocarbons (PFCs)
6. Sulphur hexafluoride (SF_6)

. 5, 10, 11, 14, 17–21, 23–28, 30, 40, 43–45, 55–58, 63

Intergovernmental Panel on Climate Change (IPCC) The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. Source: http://www.ipcc.ch. 26

Kyoto Protocol At the 'Third Conference of the Contracting Parties' to the UNFCCC, which took place in Kyoto/Japan in December 1997, the participating countries adopted a protocol additional to the UNFCCC. This 'Kyoto Protocol' came into effect legally in 2005 and expires in 2012. The protocol sets a specific time period – known as the *first commitment period* – for Annex I Countries to achieve their GHG emission reduction and limitation commitments: 2008-2012. The protocol has put in place an accounting and compliance system, in particular, laying down specific rules concerning the *reporting of information* by Annex I Countries that have to demonstrate that they meet their commitments. Rules have also been established for the accounting of assigned amounts and the trading of Kyoto units. The compliance system established by the Protocol is one of the most comprehensive and rigorous systems to be found in international treaties. 26, 49, 56–58, 60

life cycle analysis (LCA) Adapted from Djomo et al. [2011]: The LCA methodology provides a consistent framework for the assessment of environmental aspects and potential impacts associated with a product or service. The methodology is laid out in the according ISO standard 14040. The analysis quantifies the environmental impacts resulting from the provision of a particular product or service, and expresses them relative to a 'functional unit' (i.e., a unit that measures the usefulness of this system). An example for a functional unit is one kWh of electricity. 60

litter (litter fall or forest floor) Debris such as leaves and twigs falling off a tree to the ground thereby recirculating nutrients to the soil. To be precise, 'litterfall' is actually the process of litter falling off the tree not the material itself, however it is often used as a synonym for the material 'litter'. Parts of litter are listed in IPCC (Intergovernmental Panel on Climate Change) [2006] as 'leaves, twigs and small branches, fruits, flowers, roots, and bark'. Adapted from the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006] it reads: 'Includes all non-living biomass with a size greater than the limit for soil organic carbon (suggested 2mm) and less than the minimum diameter chosen for dead wood (e.g., 10cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil'. See also turnover (biomass). 7, 8, 56, 62

methodological CDM tool From UNFCCC [2010]: 'Methodological tools are generic modules that can be referenced in large scale and small scale methodologies in order to determine a specific condition (e.g. additionality of a CDM project) or to calculate particular emissions (e.g. emissions from electricity consumption). It is stated in the CDM methodology if a methodology requires application of a certain methodological tool'. They are usually papers of about 2-6 pages including decision tree charts etc. Actually the papers are rather a description of *procedures*. 25

nitrogen emissions from soil Soil nitrogen is lost via erosion, percolation (leaching), crop harvest, denitrification and volatilization and burning (Nair [1993]). Losses in the gaseous form of N_2O and NO_x are mainly produced in soils as a byproduct of nitrification (in plant production and agricultural soils, where pH is likely to be maintained above 5.0, nitrification is considered to be the dominant pathway of NO emission, EEA [2009], chapter 4.D, Crop production and agricultural soils) and denitrification. Emissions are stimulated directly by nitrogen fertilisation of forests and drainage of wet soils (adapted from Penman et al. [2003]). On the other hand, poor soil aeration such as caused by the soil compaction via heavy machinery, reduces plant growth and induces loss of soil nitrogen and production of greenhouse gases through denitrification in anaerobic sites (adapted from `http://eusoils.jrc.ec.europa.eu/library/themes/compaction/`). Peaks in NO emission are therefore likely following the application of NH_4+-based N-fertilisers, incorporation of crop residues and tillage of soils (Penman et al. [2003]). Nitrification-denitrification is used widely for the removal of nitrogen in the biological treatment of municipal and industrial wastewaters with negligible N_2O emissions (IPCC (Intergovernmental Panel on Climate Change) [2006]). 17

Non Annex I countries 'Annex I' refers to the according annex of the UNFCCC. Non 'Annex I' countries are countries not listed in this 'Annex I'. Sometimes also referred to as 'CDM countries'. Mostly this term is used in the Benwood project for indicating countries with a *low share in mechanisation and low labour cost*. The complete list of these countries can be found at the website of the UNFCCC secretariate at `http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php`. 5, 6, 11, 15, 17

pre-combustion process Describes the ensemble of upstream processes required for the production (and delivery) of a certain product such as oil, wood pellets etc. For instance the power plant producing the electricity for a pellets press, the truck delivering the pellets etc. Used in particular within energy management issues and therein within life cycle analyis. 24

Project Design Document (PDD) A Project Design Document, understood within the framework of the Kyoto Protocol. It describes an project according to a template predefined by the UNFCCC. Submitting a project for validation and registration, beforehand a PDD has to be submitted by the project developer. To get an idea, already submitted CDM PDDs (existing project proposals) may be downloaded at `http://cdm.unfccc.int/Projects/projsearch.html`. 12, 31

root-to-shoot ratio From the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: 'Ratio of below-ground biomass to above-ground biomass; applies to above-ground biomass, above-ground biomass growth, biomass removals and may differ for these components.'. 48, 56

Secretariat of the United Nations Framework Convention on Climate Change An organisation managing the issues of the UNFCCC. Headquarters are in Bonn/Germany. Website: `http://unfccc.int`. 56, 60, 63

short rotation coppice (SRC) Intensive SRF practice using fast-growing tree species with an ability to coppice from harvested stumps, i.e., new shoots can emerge from the rootstocks or stools. Harvests are performed in short intervals (2–6 years) depending on plant material, growth conditions and management practices. Planting, maintenance and harvesting is predominantly done by established agricultural practices allowing farmers to use methods and machines already known from annual crops. According to this definition, SRC falls within SRF and simply represents a more specialized practice of SRF. 6, 7, 15, 60

short rotation forestry (SRF) A forest production practice for dendromass, here (i.e. in the BENWOOD project) mostly for energy purposes, with the basic principle to grow fast-growing deciduous tree species on forest or agricultural land at a denser spacing and with elevated maintenance (e. g. regarding weed control, irrigation) than in traditional forestry. The biomass is harvested when the trees have reached a size that is easily handled and economically sound, typically after c. 2 to 25 years. The size at harvest depends on plant material, growth conditions, culture technology and desired end-product, and is frequently between 10 and 20 cm diameter at breast height. SRF may be regarded as forestry or agricultural practice, depending on whether the plantations are grown on forest or agricultural land. To make a sharp distinction between forestry and short rotation forestry is often impossible. A subcategory of short rotation forestry is short rotation coppice (SRC). 5–7, 10, 11, 15, 18–24, 27, 28, 30, 45, 46, 49, 56, 60

soil organic carbon Carbon contained in soil organic matter with a grain size < 2 mm. The grain size limit relates to the analytical method which involves sieving (removal of coarse material such as pebbles) of the homogenized soil sample after macroscopic plant remains (mainly roots) have been removed manually. In most soils in non-arid regions soil organic carbon coincides with the total carbon in the soil because the majority of soils has negligible contents of elemental or inorganic carbon (Schumacher [2002], p. 5). Soil surface layers (0-20 cm depth) seldom contain more than 5 percent soil carbon (Buringh [1984]). Soil carbon contents are higher in humid climates and lower in hot and dry climates (Buringh [1984]).

Adapted from the glossary part of IPCC (Intergovernmental Panel on Climate Change) [2006]: Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series. Live and dead fine roots and DOM within the soil, that are less than the minimum diameter limit (suggested 2mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically (sieving). The default for soil depth is 30cm'.

The following example (Buringh [1984]) gives an idea about the quantity of soil organic carbon contained in one hectare.

> A soil with a bulk density of 1.5, and a carbon content of 3 percent in the 0 to 25 cm layer, 1 percent in the 25 to 50 cm layer, 0.3 percent in the 50 to 75 cm layer and 0.1 percent in the 75 to 100 cm layer, contains 165 t C/ha; the 0 to 25 cm layer contains 113 t/ha, or 68 percent of the total.
> In a true chernozem (black earth, or mollisol) the total soil carbon is more than 200 t/ha and the surface layer of 0-25 cm contains only 25 percent of the carbon because the humus layer is very deep. Also histosols (peat soils) contain a considerable amount of organic carbon. In the analysis on 400 soils performed in Buringh [1984] the maximum soil carbon content was 801 t C/ha in a hydromorphic volcanic soil and the minimum soil carbon content was less than 10 t C/ha in a desert soil. More than half of all the soils studied had a soil carbon content of *less than 150 t C/ha*.

Soil organic carbon is closely related to soil organic matter with carbon accounting generally for about 58 percent of the organic matter content ('van Bemmelen factor', although in the tropics this factor often comes down to 45 to 55 percent, Buringh [1984], p. 93).

Instructions on how to measure soil organic carbon are provided in Pearson et al. [2005], p. 23, or in greater detail in Schumacher [2002]. The majority of the large spectrum of available analytical methods is based on the destruction (chemical, thermal) of the organic carbon compounds and then measuring the residues of the destruction (e.g. measurement of the generated CO_2 or of chemical residues remaining from the chemical destruction of the carbon compounds). 7, 8, 57, 59, 61

soil organic matter Organic part of the soil. Soil organic matter is closely related to soil organic carbon because it is usually via the assessment of soil organic carbon that the amount of soil organic matter is determined (Schumacher [2002]). Soil organic matter consists of (Buringh [1984])

1. living plant roots (however, when it comes to determine the soil organic carbon see the according remark there on the max. diameter)
2. dead but little-altered plant remains,
3. partly decomposed plant remains,

4. colloidal organic matter, being the humus proper-often some 60 to 70 per cent of the total organic matter in soils,
5. living microorganisms (bacteria, fungi, protozoans, etc.) and macroorganisms (worms, ants, termites, etc.),
6. inactive or inert organic matter (coal, burned vegetation or ash fertilizer).

Organic material lying on top of the soil (e. g. dead leaves and litter) is not included in the calculation of organic carbon and has to be accordingly removed during sample taking.

Further from Buringh [1984]: Although organic matter is often present in the soil to a depth of 1 or 1.5 m, most is in a surface layer of from 1 to 20 cm.

Under *natural conditions* the content of organic matter in soil *is constant*; the rate of decomposition is equal to the rate of supply of organic matter from plants.

The equilibrium is disturbed when forests are cleared and the land is used for agriculture. There is also a decline in organic matter when grassland in the tropics and subtropics is transformed into cropland, or when savannahs are burned. The decline is rapid in the first few years after deforestation and gradually slows over the next 10 to 50 years. Organic matter is also lost through misuse or deterioration of land (soil erosion, salinization, alkalization and soil degradation), and because of the increasing non-agricultural use of land (urbanization and highway construction).

On the other hand, there may be an increase in organic matter when good farm management is practised and organic manure and compost are used, when arid land is irrigated, or where agricultural land is reforested

On organic matter and carbon in forest soils (from Penman et al. [2003]):

Because the input of organic matter is largely from aboveground litter, forest soil organic matter tends to concentrate in the upper soil horizons, with roughly *half of the soil organic carbon* of the top 100 cm of mineral soil being held in the *upper 30 cm layer*. The carbon held in the upper profile is often the most chemically decomposable, and the most directly exposed to natural and anthropogenic disturbances . 7, 56, 61

standard cord of wood 3,62 m^3 (128 cubic feet) of stacked wood including bark. A full cord measures four feet by four feet by eight feet (1.21 by 1.21 by 2.43 meters). The concept of a cord of wood emerged in the 17th century, when stacks of wood were literally measured with a cord. 62

stère The stère is typically used as a volume measure for large quantities of firewood or other cut wood. It is the wood contained in one cubic meter filled with stacked wood logs, branches etc. Hence, all (air) gaps between the stacked wood are included in the stère. See also standard cord of wood. 58

terra preta Def. from Verheijen et al. [2010]: Colloquial term for a kind of Anthrosol where charcoal (or biochar) has been applied to soil along with many other materials, including pottery shards, turtle shells, animal and fish bones, etc. Originally found in Brazil. From the Portuguese 'terra' meaning 'earth' and 'preta' meaning 'black'. See also biochar. 6, 56

turnover (biomass) Annual rate of mortality of the biomass component in question (foliage, branches, roots). A turnover rate of 0.3 means that 30% of the total biomass of the component is converted to litter (litter fall or forest floor) (where 'litter' here also applies to dead roots) every year. Modified from: Schelhaas et al. [2004]. 59

United Nations Framework Convention on Climate Change (UNFCCC) http://unfccc.int. The UNFCCC was one of three conventions adopted at the 1992 'Rio Earth Summit'. It is a frameworking convention to stabilize GHG concentrations at an 'acceptable' level. Most important element of the convention is the assignment of emission reduction caps to countries. In expert papers the UNFCCC is also sometimes only briefly referred to as 'the Convention'. The implementation of the convention is managed by the according UNFCCC secretariate. 26, 27, 56, 58–60

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